Research article

Reducing Nitrogen Emission during Cow Manure Composting with Adding of Rice Husk Biochar

SAVESH MASKEY
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan
Email: smaskey27@gmail.com

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

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Abstract Nitrogen losses in the forms of ammonia and nitrous oxide emission are major causes for low nitrogen content in cow manure compost. In addition, nitrogen losses decrease the agronomic value of compost. In this study, rice husk biochar was added in cow manure to assess its effects on reducing nitrogen losses. Rice husk biochar is a product of thermochemical reaction in limited oxygen supply resulting in a product with micro-pores and large surface area with negative charge. A small scale composting experiment was designed and conducted using cow manure for a period of 60 days. Gases released were measured periodically with static gas chamber method. In addition, total nitrogen content and C/N ratio were analyzed. The experiment results showed that the loss of ammonia which is in peak during initial stages were lower in the treatments added with biochar. The cumulative ammonia emission was lowered by 12.6%, 14.5% and 23.2% in 5%, 10% and 15% biochar added treatments respectively, as compared to control. The cumulative gas flux result of N_2O showed similar trend to that of NH_3. N_2O emission was lowered by 40.0%, 46.4% and 60.4% in 5%, 10% and 15% biochar added treatments respectively, as compared to control. Furthermore, total nitrogen content and C/N ratio had better results in biochar added treatments. The obtained results may be attributed to the fact that micro-pores and negative charge in rice husk biochar adsorbed the nitrogenous compounds. Additionally, biochar increased retention of moisture and nutrients enhancing microbial activity for better degradation and humification of organic matter. The results indicated that biochar could be a good medium in reducing the nitrogen loss and increasing agronomic value during composting of cow manure.

Keywords cow manure composting, nitrogen emission, rice husk biochar, agronomic value

INTRODUCTION

Composting is a sustainable method for waste management of cow manure. It is a naturally occurring process where various distinctive microorganisms break down organic matter to produce humus like substance, which has high agronomic value. On the other hand, composting produces harmful gases like ammonia (NH_3) and nitrous oxide (N_2O), which causes environmental problems. High nitrogen content of cow manure causes the release of NH_3, which is one of the principal malodorous compounds produced during composting. Aerobic degradation of organic material in cow manure causes intensive NH_3 generation and emission. Ammonia volatilization leads to the loss of nitrogen and effects compost nutrition content (Pagans et al., 2006). N_2O is released from nitrification or denitrification (Fig.1) of nitrogenous compounds and has a high global warming potential (Houghton et al., 1992). Nitrous oxide is considered 265 times more potential GHG than carbon dioxide (IPCC, 2013). Emission of these gases causes loss of nitrogen, which decreases the agronomic value of compost. Loss of nitrogen through ammonia volatilization can be as high as 70% (Martin and Dewaes, 1992; Eghball et al., 1997; Beck-Friss et al., 2001) and 0.62 to 1.07% in the form of N_2O in manure (Hao et al., 2001). Nitrogen transformation during of manure composting is a complex mechanism and is shown in Fig. 1 (Wu et al., 2012). It is of great concern on developing measures for reducing nitrogen losses during composting process to minimize the emission of hazardous gases and increase the agronomic value of compost.

Recently, biochar amendment has been used in limiting N_2O emission in manure composting and soil (Kamman et al. 2015; Wang et al. 2013). Biochar is a carbon rich material derived from pyrolysis of biomass characterized by high number of micro pores and large surface area with negative charge. In this study, it is speculated that these properties of biochar can reduce the emission of NH_3 and N_2O when composted with animal manure as biochar can effectively retain NH_3, NH_4^+ and NO_3^- in animal manure (Steiner et al., 2010).

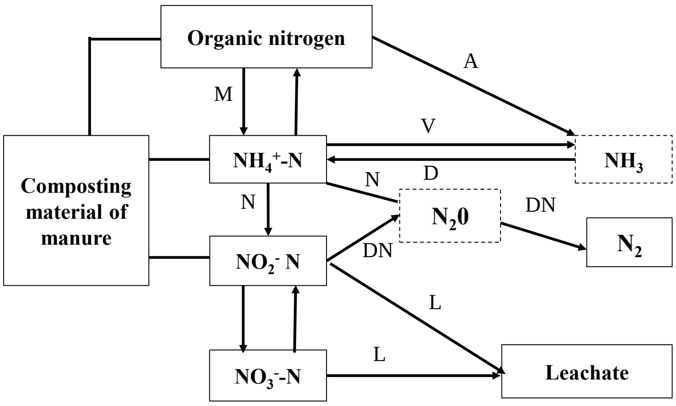

Fig. 1 Nitrogen transformation during manure composting (adopted from Wu et al., 2012)
A: Ammonification; I: Immobilization; M: Mineralization; V: Volatilization;
D: Dissolution; Nf: N-fixation; N: Nitrification; DN: Denitrification; L: Leaching loss

Therefore, this study concentrates to evaluate the effects of composting cow manure with rice husk biochar amendment to reduce the emission of NH_3 and N_2O and increase the agronomic value of compost.

METHODOLOGY

Designing of Compost Box and Gas Chamber

A compost box was designed using glass container of dimension 30 cm^3. The glass box was covered with styro-foam sheets of thickness 4 cm on five sides for minimizing the heat loss (Fig. 2).

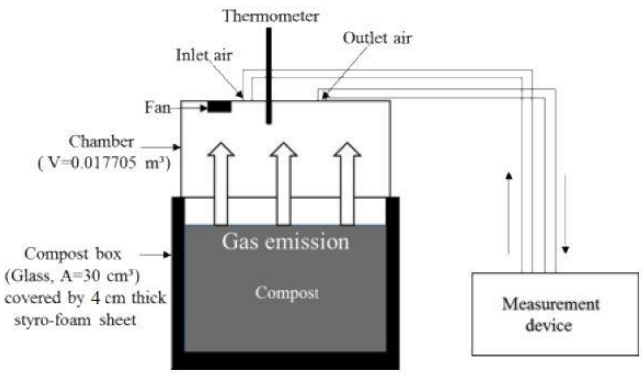

Fig. 2 Schematic diagram of composting box and gas flux analysis

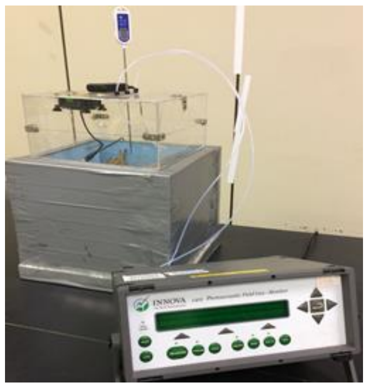

Fig. 3 Apparatus used during gas flux measurement

A static gas chamber was designed to measure the gas flux. A digital thermometer and a fan were attached inside the chamber for measuring temperature and uniform circulation of air during measurement of gas respectively (Figs. 2 and 3). The volume of air inside the chamber was calculated as 0.017705 m^3.

Conditions of the Experiment

The composting experiment was conducted from 8 August 2019 to 7 October 2019 in Laboratory of Land and Water Use Engineering, Tokyo University of Agriculture. The average temperature was 23.0℃ during the experiment. Cow manure, rice straw and litter was used as main components for composting. The nitrogen content in cow manure and rice husk biochar was 23695 mg/kg and 1241 mg/kg respectively at the start of the experiment. Rice husk biochar was added in three different variations (Table 1). The initial water content of the composting material was set at 70±2% for all the treatments.

Table 1 Composition of treatments

Composition	Control	Treatment with 5% added biochar	Treatment with 10% added biochar	Treatment with 15% added biochar
Cow manure (g)	3200	3200	3200	3200
Litter + rice straw (g)	1800*	1800*	1800*	1800*
Rice husk bio-char (g)		250*	500*	750*

*Note: * represents air-dry weight basis*

Measurement of Gas Emission

Gas flux was measured using static gas chamber method with photoacoustic spectrometer. The spectrometer used in this study was INNOVA 1412 Photoacoustic Field Gas Monitor (Fig. 3). Gas flux was calculated using linear aggression method showed in Equation 1 (Minamikawa et al., 2015).

$$F = \rho \times \frac{V}{A} \times \frac{\triangle c}{\triangle t} \times \frac{273}{T} \tag{1}$$

where F is gas flux (mg m^{-2} hr^{-1}), ρ is density of gas (kg m^{-3}) where density of NH_3 is 0.772 kg m^{-3} and of N_2O is 1.96 kg m^{-3}, A is bottom surface area of chamber (m^2), V is volume of air inside the chamber (m^3), △c/△t is average increase rate of gas density inside the chamber (10^{-6} m^3 m^{-3} hr^{-1}), T is average temperature inside the chamber (K).

Compost Sampling and Analysis

Compost was sampled at 5, 10, 20, 30, 40 and 60 days to analyze its agronomic value. Temperature of the compost pile was measured using Custom CT-0580 data logger and digital thermometer on daily basis. Water content of the sample was analyzed using gravimetric method, where samples were kept at 105°C for 24 hours. Carbon content was determined by using the formula C=0.580* IL. Total nitrogen was analyzed by absorption spectroscopy using HC-1000 (Central Science Corp.) as measurement device (Mihara and Ueno, 2000).

RESULTS AND DISCUSSION

Biochar Effects on Composting Temperature

Temperature of composting process is widely considered as significant factor in gas emission during cow manure composting as microbial metabolism and activities are all temperature sensitive and dependent. NH_3 is released when the temperature is high and are carried by thermophiles. Whereas, N_2O is released after temperature declines and mesophiles are responsible for it. In this study, all the treatments showed a similar pattern of temperature evolution with a rapid activation of composting process carried by intensive microbiological degradation of organic matter. Biochar added treatments had increased temperature profile during the thermophilic phase compared to control (Fig. 4). The result coincides with previous studies using biochar as a co-substrate for manure composting (Jindo et al., 2012; Wang et al., 2013; Wei et al., 2014). It is speculated that higher temperatures in biochar added treatments were attributed to the structure of biochar, which provided suitable habitat conditions with positive effects on substrate properties such as porosity, surface area and moisture content. These factors promoted microbial activity, explaining higher temperatures.

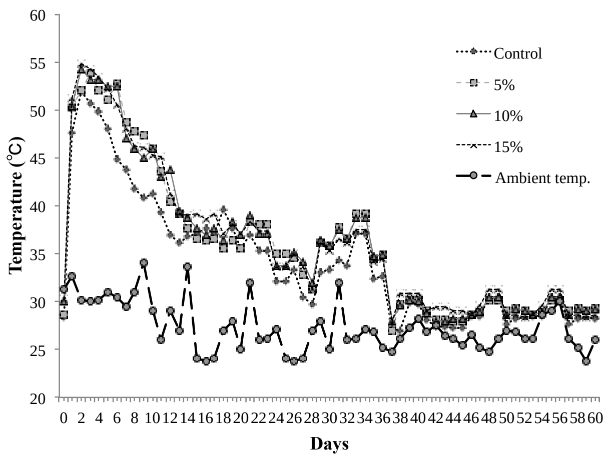

Fig. 4 Periodic changes in temperature with time

Biochar Effect on Ammonia Emission

Ammonia emission is inevitable during cow manure composting which has high content of nitrogen. Generally, emission is high during early stage of composting where temperature and pH are high. In this study, emission was high during the first week of composting which lowered gradually as the temperature decreased for all the treatments (Fig. 5) with negligible emission after 20 days of composting. The emission pattern of the results of this study coincides to that of Osada et al. (2000) and Kuroda et al. (1996). The total ammonia emissions were significantly lower in biochar amended treatments with 15% added treatment having the lowest emission.

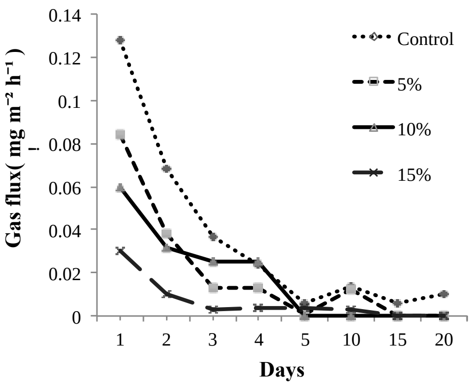

Fig. 5 Periodic changes in ammonia flux

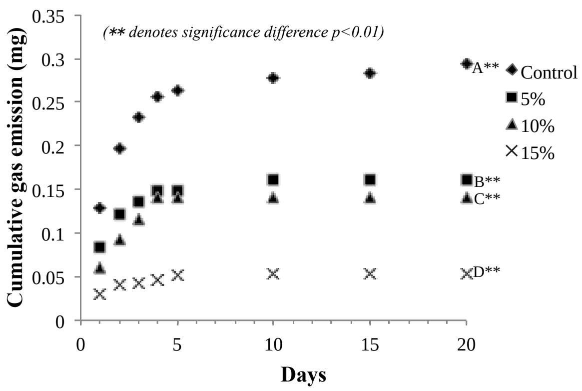

Fig. 6 Cumulative ammonia emission

The cumulative gas emission was lowered by 12.6%, 14.5% and 23.2% in 5%, 10% and 15% biochar added treatments respectively, as compared to control (Fig. 6). The reduced emission can be attributed to the microscopic porous structure having negative charge adsorbing ammonium ions by electrostatic attraction (Montes-Moran et al., 2004; Nguyen et al., 2017).

Biochar Effect on Nitrous oxide Emission

Composting of high organic content materials has been shown to produce N_2O by nitrification and denitrification under aerobic and low oxygen conditions respectively. Fig. 7 shows the periodic change in emission between the treatments. The cumulative gas flux resulted in least emission in 15%, 10% and 5% biochar added treatments followed by control (Fig. 8). The cumulative gas emission was lowered by 40.0%, 46.4% and 60.4% in 5%, 10% and 15% biochar added treatments respectively, as compared to control. The result observed is supported by that of Jeffery et al., 2015, which states that addition of biochar can decrease the emission of nitrous oxide.

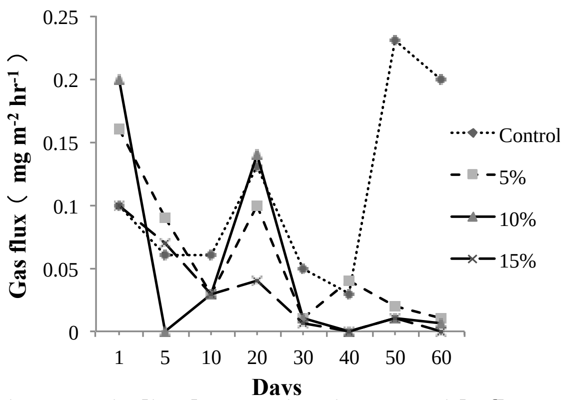

Fig. 7 Periodic changes in nitrous oxide flux

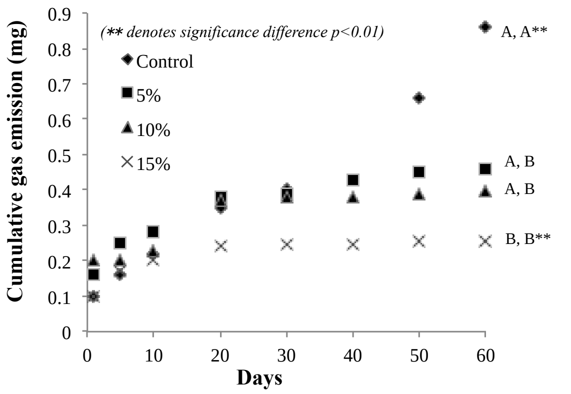

Fig. 8 Cumulative nitrous oxide emission

Biochar Effects on Agronomic Value of Compost

Nitrogen content and C/N ratio are oftenly used as a criteria for determining the agronomic value of compost. Nitrogen is the most esential plant nutrient for growth and development of plants. Compost which has high nitrogen content is considered having high agronomic value. The experimental results showed that total nitrogen content of biochar added treatments were higher than control (Fig. 9) at 60 days of composting with 99% significant difference. The high nitrogen content in biochar added treatments can be due to the result of reduced emission of NH_3 and N_2O.

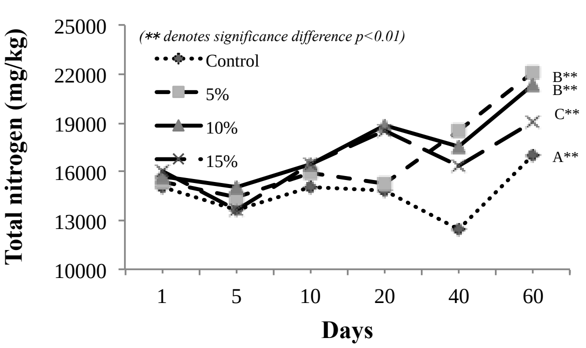

Fig. 9 Periodic changes in nitrogen content

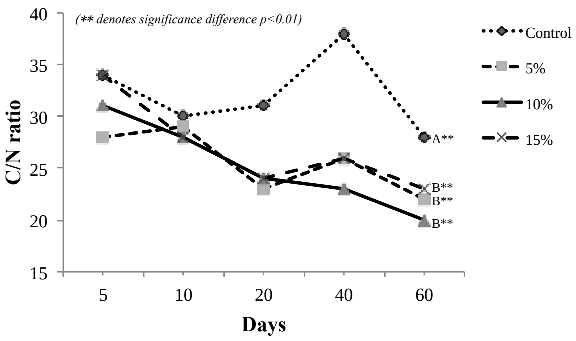

Fig. 10 Periodic changes in C/N ratio

In addition, biochar may have enhanced aeration, water holding capacity and microbial activity increasing humification of organic material. This resulted in high nitrogen content and concurrs to that of Akdeniz (2019), El-Naggar et al. (2019) and Godlewska et al. (2017). C/N ratio is used as an indicator of compost stability and nitrogen availability. The periodic change of C/N ratio showed better values in biochar added treatments compared to control (Fig. 10). The C/N value of biochar added treatments at 60 days of composting had siginificant difference at 99%, compared to control. This can be explained as increased surface area and moisture content favoured compost microorganisms for degradation and humification of organic material. Also, biochar addition increased sorption of nitrogen compounds in the microspores providing microorganism with sufficient nitrogen for their metabolism.

CONCLUSION

This study discusses the effects of composting cow manure with rice husk biochar in reducing the emission of NH_3 and N_2O and increasing the agronomic value of compost. A small scale laboratory experiment was conducted where rice husk biochar were composted with cow manure The results showed that addition of biochar is effective in reducing emission of NH_3 and N_2O with 15% treatment being the most efficient. This can be attributed to the structure of biochar with high number of micropores and surface area that enables absorption / adsorption of NH_3, N_2O, water soluble NH_4^+ as well as NO_3^-. The result also showed better nitrogen content and C/N ratio in biochar-amended treatments. The author speculates that adding of biochar helped in increasing oxygen content and retention of water enhancing better microbial metabolism and mineralization. The author believes that composting biochar with cow manure is encouraging method for reducing emission and increasing better quality compost. However, further researches are needed to understand the role of biochar and interaction of manure, biochar and microbes during composting process.

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