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Allantoin-N concentration changes and analysis of the influencing factors on its changes during different manure composting

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ABSTRACT

Allantoin is one of important nitrogenous compounds in manure. In this study, the simulation experiment of aerobic composting was adopted to explore concentration changes, degradation and relevant influencing factors of allantoin-N during six manure composting. The result showed that the allantoin-N concentration was markedly different among different manures. The various livestock and poultry excreted 1.92–11.14 g kg^{-1} allantoin-N which accounted for 9.98–32.27% of the total excreted nitrogen. The changing trend of the allantoin-N concentration firstly increased (for 0–14 days), then decreased (for 14–70 days) during different manure composting, and the allantoin-N concentration after composting was lower than the initial allantoin-N concentration in all manure composting. During allantoin degradation for 14–70 days of composting, the half-life of allantoin-N was 57.76 days in broiler manure, 46.21 days in layer-hen manure, 27.73 days in hog manure, 25.67 days in sow manure, 38.51 days in young pig manure and 15.75 days in dairy manure, and the sequence in the half-life was chicken manure > pig manure > dairy manure. Allantoin degradation conformed to first-order kinetics. Through the correlation analysis, hippuric acid, hydrolyzable nitrogen, amino acid–nitrogen, HUN fraction, NO_3^-—N and total hydrolyzable nitrogen could be closely related to allantoin-N transforming during composting. Humification could be the main influencing factor for reducing allantoin-N concentration during composting.

1. Introduction

Allantoin as an end product of purine metabolism, it has been of widespread occurrence in animals and some plants. At present, the metabolic process and physiological function of allantoin in a plant have been better investigated. Generally speaking, allantoin can be synthesised in some plants, and is one of the main nitrogen transporting compounds found in the xylem sap of many nodulated tropical legumes. In nodulated *Vigna* ureides may account for 75% of the nitrogen transported in the xylem but it may reach as much as 95% (Pate, 1973). Detailed investigations have been made on the biosynthetic route of allantoin, together with the distribution of these ureides throughout the plant, their catabolism with the transfer of nitrogen to amino acids, as well as the control of these metabolic steps, such that nowadays the whole process is well understood, including at the gene level (Crawford et al., 2000). In animals, allantoin is also one of excretion of purine derivatives and it is directly degradative products of uric acid in liver (Tas and Susenbeth, 2007). The enzyme uricase oxidizes uric acid to allantoin. The hydrolysis of allantoin to allantoic acid is catalysed by the enzyme allantoinase. Allantoin cannot be utilised by the tissues, and is excreted mainly in urine, but also secreted in saliva and milk (Tas and Susenbeth, 2007). For example, in dairy urine, allantoin is the main purine derivative ($\geqslant$0.80 of total purine derivative) (Chen et al., 1990). In some experiments allantoin in dairy cows was a constant molar proportion of purine derivative excretion with 0.876 ± 0.038 (Dewhurst et al., 1996) and with 0.906 mol/mol (Vagnoni et al., 1997), but in other experiments it varied depending on diets (Stefanon et al., 1995; Martín-Orúe et al., 2000; Reynal et al., 2005), and the physiological state of the animal (Stefanon et al., 1995; Johnson et al., 1998). Ultimately, allantoin, as one of the main nitrogen transporting compounds, is remained in manure when urine and feces are mixed together.

Allantoin is an important plant growth regulator and can be taken up by plants, with the function of promoting crop germination and growth. It was reported that allantoin as seed soaking solution can promote seed germination, young plant growth and nutrient absorption (Lin et al., 1996). Romuld (1983) found that allantoin can promote the metabolic process and growth of chlorella and alga. John (1986) reported that plant growth was accelerated with high crop output and nitrogen in soybean, with application of allantoin or allantoin +NO_3^-—N in fruit period of soybean. However, overtop allantoin concentration can easily generate the alteration

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of molecular mechanisms in a plant. Vacic and Gajic (1983) reported that allantoin concentration with 1×10^6 g/L can change nucleic acid in wheat. With the land application of manure or manure composting, allantoin enters into soil environment. So we should investigate the allantoin change during composting and allantoin concentration in composting products, which will help us to explore the allantoin function on crop growth in manure or soil environment.

Allantoin is also one of important nitrogenous compounds in manure, but information on the concentration of allantoin in manure is rare. It was reported that there is 2.2–22.2% of allantoin in dairy urine (Doak, 1952; Bussink and Oenema, 1998). It is well known that composting is one of the disposal ways for manure waste. Manure composting is proven to be an attractive material for improving soil structure in tilled soils and increasing dry matter production in grassland soils, owing to its high organic matter content and availability of essential plant nutrients as the fertilizer. Because of this function, it is important to identify the variability in composition of manure composting in order to evaluate its merit as a fertilizer/soil conditioner, especially nitrogen composition. Nitrogen transformation during composting is very complicated, because various nitrogenous compounds can be transformed continuously with accompanying nitrogen loss. At present, some nitrogenous compounds in manure composting has been well understood, for example, total nitrogen, organic nitrogen, ammonia (NH_3), N_2O, NO_3^-—N (Szanto et al., 2007; Liang et al., 2006; Alkoaik and Ghaly, 2006; Wang et al., 2004; Sommer, 2001; Tiquia and Tam, 2000), but allantoin changes during manure composting has not been investigated. Because of its important function on plant growth, it is necessary to make more investigation on allantoin during composting with the application of manure composting as the fertilizer.

Experiments were conducted on the fate of allantoin-N during composting. Results of the experiments with regard to allantoin-N concentrations in manure, its degradation and factors affecting the allantoin change provided additional insights into the composting process and are described here. The objectives of this work were (i) to quantify the dynamics of allantoin-N concentrations and degradation of allantoin during different manure composting; and (ii) to evaluate the influencing factors of allantoin-N changes during composting.

2. Methods

2.1. Manure collection and characterization

In this experiment, six manure samples including broiler manure, layer-hen manure, hog manure, sow manure, young pig manure and dairy manure were collected from different large-scale intensive livestock farms in the Shenyang suburb, Northeast China. The moisture content in all fresh manure was higher than 60%, even in young pig manure with 86% of the moisture content. So a part of moisture of fresh collected manures should be dehydrated in shady and cool environment before manure composting. The manure composting in the study was alone manure without adding any other materials in order to avoid the effect of addition agents on the allantoin-N change during composting, and was tested in duplicated for each manure bulking. Some important properties of different manures were analysed in duplicate. Table 1 shows the main chemical properties of different manures.

Table 1
Some properties of different manures

	pH 10:1 H_2O	Total C/g kg^{-1}	Total N/g kg^{-1}	C/N	Total P/g kg^{-1}
Broiler manure	6.02	325.4	34.01	9.561	7.550
Layer-hen manure	7.05	313.1	34.53	9.070	9.360
Hog manure	6.51	410.1	26.72	15.34	15.42
Sow manure	6.50	388.2	28.63	13.56	17.46
Young pig manure	7.04	338.7	35.02	9.670	22.06
Dairy manure	6.53	418.3	16.03	26.10	5.000

2.2. Aerobic composting experimental design

The aerobic composting experiment of manure was performed using 18 identical plastic lab vessels, with 0.45 m high and 0.25 m in diameter. Every manure composting was made on three replicates. The wall of plastic lab vessels had many small pores for better aeration of manure composting. Different lab vessel containers contained 4.0 kg (on dry weight basis) manure materials. All manures used to compost should be piled up at the darkness and humidification in an incubator with the function of adjusting temperature. At the beginning of the composting process, the moisture content of the manure in each container should be kept at 50–60% for better composting. In the present study, the suitable moisture content in broiler manure, layer-hen manure, hog manure, sow manure, young pig manure and dairy manure composting was 52%, 54%, 53%, 54%, 50%, and 60%, respectively. To prevent moisture loss, the experimental vessels were covered with paddy straw. The manure moisture was controlled at 1-day intervals by adding enough water to obtain the moisture content of initial manure materials throughout the composting period. The manure was turned at 1-day intervals during the first 28 days of composting and at 4-day intervals thereafter until day 70 in order to ensure both adequate porosity for maintaining aerobic conditions and the homogeneity of the materials.

Temperature was measured daily by a digital thermometer in the centre of the composts, moreover adequate time (10 min) was taken to read the temperature twice every day until no further temperature changes. In order to avoid composting heat loss and outside environmental heating, temperature of the incubator was adjusted to assure that temperature of manure was lower 1–2 °C than its incubator every day (Lin et al., 1996). From 28 days of composting, composting temperature of six manure samples kept stable at 30 °C, that is, exterior and interior pile temperatures showed a steady rate of decline after the piles were turned. Samples were taken from different manures at day 0, 7, 14, 28, 42, 56 and 70 of composting for determination pH values and various nitrogenous compounds concentrations. Sampling was carried out with a hand auger for pedology, during which each sample was obtained by mixing subsamples from approximately 15 separate points within the composting heap. Samples were stored at −20 °C prior to analysis of pH values, allantoin and hippuric acid. The samples collected during different manure composting periods in the experiment were air dried at room-temperature under shady and cool environment, chopped and sieved (<2 mm). Then treated composting samples were used to analyse various nitrogenous compounds containing total nitrogen, hydrolyzable nitrogen, total hydrolyzable nitrogen, ammonia nitrogen, amino acid–nitrogen, amino sugar–nitrogen, HUN fraction (hydrolyzable unidentified nitrogen), UN (unhydrolyzable nitrogen), NH_4^+—N and NO_3^-—N.

2.3. Determination of all nitrogenous compounds and pH values

The moisture content of the fresh samples was determined as weight loss upon drying at 105 °C in an oven for 24 h, or until no changes in weight were observed. All results reported in the work are the means of determinations made on three replicates and expressed on a dry weight basis, except for the moisture content. The pH values in H_2O were determined with 1:10 (w/w) soil to solution