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Evaluation of pilot-scale in-vessel composting for Hanwoo manure management

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ABSTRACT

The study investigated the effect of in-vessel composting process on Hanwoo manure in two different South Korea regions (Pyeongchang and Goechang) with sawdust using vertical cylindrical in-vessel bioreactor for 42 days. The stability and quality of Hanwoo manure in both regions were improved and confirmed through the positive changes in physico-chemical and phytotoxic properties using different commercial seed crops. The pH and electrical conductivity (EC, ds/m) of composted manure in both regions were slightly increased. At the same time, carbon:nitrogen (C:N) ratio and ammonium nitrogen:nitrate nitrogen (NH_4^+-N:NO_3^--N) ratio decreased to 13.4–16.1 and 0.36–0.37, respectively. The germination index (GI, %) index was recorded in the range of 67.6–120.9%, which was greater than 50%, indicating phytotoxin-free compost. Although, composted manure values in Goechang region were better in significant parameters, overall results confirmed that the composting process could lead to complete maturation of the composted product in both regions.

1. Introduction

Hanwoo (*Bos taurus coreanae*), also known as Korean native cattle, refers to a breed of cattle raised in Korea. It has been used for transportation and farming for a long time. It has been the only cattle breed in Korean peninsula for over 5000 years. This Hanwoo species is known to be a crossbred species between *Bos indicus* from India and *Bos primigenius* from Europe (Do et al., 2016). According to reports from the Ministry of Environment (ME) in Korea, Hanwoo is categorized as the main livestock in Korea. Its number was recorded at 3.16 million in 2012. Since then, the number of livestock has been increased (Won et al., 2015). In South Korea, the amount of livestock manure generated in 2008 was estimated at 4174 million tons. It was remarkably increased to 4652 million tons in 2015. Cattle manure is basically made up of digested grass and grain. It is high in organic materials with rich nutrients. The use of cattle manure on agricultural land is a popular practice around the world. Although it has nutritional value, the increase of manure from those livestock has caused concerns due to contaminants such as ammonia and heavy metals. Such manure can contaminate soil and water stream. In this regard, composting process is an effective and economic approach to transform and decontaminate cattle manure for resource utilization because of its low cost, easy operations and low pollution (Yamamoto et al., 2012). Oishi et al. (2012) and Yamada et al. (2013) have suggested that cattle manure containing large amounts of organic nitrogenous compounds can be easily transformed into ammonium via ammonification. The ammonium can then be oxidized to nitrate through nitrification in the composting process.

However, Ravindran and Mnkeni (2016) and Mupambwa et al. (2016) have suggested that the composting is a time consuming process. In addition, it sometimes can result in immature composts whose soil application can cause N starvation with associated phytotoxic effects. In-vessel composting process can overcome all disadvantages (composting speed, land requirement, health standards, climatic situation, and control of exhaust air, moisture, temperature, and odor) of other composting processes. Chan et al. (2016), Wang et al. (2016) and Sangamithirai et al. (2015) have also stated the same advantages of using in-vessel composting process as proprietary technology for different types of waste, including paper waste, yard waste, and food

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waste. Several researchers have also attempted in-vessel co-composting process for different types of livestock manure such as poultry manure with wood shavings (Ahn et al., 2007), horse bedding waste with blood meal (Wong et al., 2012), chicken manure with sawdust (Khan et al., 2014), and pig manure with cornstalk and sawdust (Ren et al., 2010; Selvam et al., 2013). In this study, sawdust was used as a co-compost material for Hanwoo manure to improve aeration and compost quality. Nayak and Kalamdhad (2015) have also suggested that bulking material can improve the stability, integrity, porosity of solid matrix, and moisture adjustment for better composting process. On the other hand, Cho et al. (2017) has reported that animal manure nutrient composition and phytotoxicity might be different from region to region of the country due to land and livestock management. In this study, Pyeongchang and Goechang regions Hanwoo manure were selected based on the upland grassland regions in South Korea. Therefore, the aim of the present study was to determine the effect of in-vessel composting process on Hanwoo manure in two different South Korea regions with sawdust using vertical cylindrical in-vessel batch bioreactor.

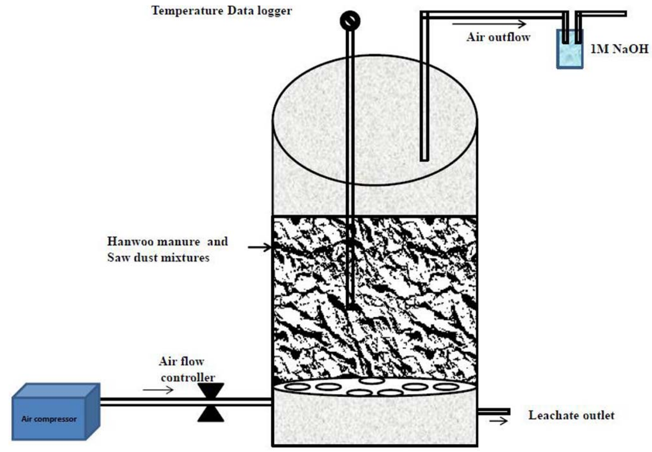

Fig. 1. In-Vessel composter for Hanwoo manure composting process.

2. Materials and methods

2.1. Raw materials

Hanwoo manure was collected from farms in two different regions (Pyeongchang and Geochang) in South Korea. The collected manure was stored in room with controlled temperature at 4 °C to avoid changes in their characteristics until the start of the study. Sawdust was collected from a sawmill located in Namwon, South Korea. Physical and chemical characteristics of manure samples and saw dust were analyzed using standard methods on dry weight basis (APHA, 2011). Since sawdust has a high C:N ratio and dry nature, it was used to adjust the water content and C:N to levels suitable for composting. Moreover, the structure of sawdust (particle density, 0.8–1.0 cm) provides adequate porosity in the compost mixtures.

2.2. Feedstock preparation and experimental design

Two different sets of composting experiments were conducted for farms in two different regions Hanwoo manure was labelled as A (Pyeongchang) or B (Geochang). This study was carried out in a temperature controlled research room (20–22 °C) of the National Institute of Animal Science (NIAS) located in Wanju-Gun/Jeonju at 35.8242° N and 127.1480° E in Jeollabuk-do, South Korea. For each set, composting was conducted in triplicates using similar sizes of pilot compost reactors with 80 kg of feedstock (initial feed mixtures with 65% moisture content) prepared with Hanwoo manure: Sawdust at ratio of 2:1 (w/w, fresh weight). These mixtures were composted for 42 days in 100-L pilot-scale stainless steel cylindrical composter (height, 0.8 m × inner diameter, 0.4 m) (Fig. 1). These reactors were designed specially to minimize heat loss using insulated polyurethane for surrounding walls. Two layers of removable plastic lid followed by stainless wire mesh were fitted to the top of each reactor vessel to facilitate emptying the reactor, mixing, and refilling during the weekly compost turning process. Temperature profiles of each reactor were monitored every day between 9:00 am and 10:00 am during the experimental period using an electronic thermometer probe. The feedstock biomass was held over a plenum using a 5-mm mesh grid. Air was forced through peristaltic pump at a flow rate of 0.1 L/min/kg feedstock biomass (Yuan et al., 2016) into the plenum and through the feedstock biomass during the composting process.

2.3. Physico-chemical and phytotoxicity analysis

The pH and electrical conductivity (EC) of the sample mixture diluted in double distilled water at a ratio of 1:10 (w/v) were determined using a pH meter (Thermo scientific, Orion 4 Star) and a conductivity meter (Yellow Springs Instrument, Model 3100). Total nitrogen and total carbon (TC) contents were determined using a Vario Macro CHNS Element Analyzer. Total phosphorus (TP) contents were analyzed using a Varian CARY 300 UV–Vis Spectrophotometer. Heavy and trace metals of arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), chromium (Cr), nickel (Ni), copper (Cu), and zinc (Zn) were determined by means of inductively coupled plasmaoptical emission spectrometer (ICP-OES) (Varian Inc., The Netherlands) after digesting the sample with concentrated HNO_3/concentrated $HClO_4$ (2:1, v/v). Ammonium-nitrogen (NH_4^+-N) and nitrate nitrogen (NO_3^--N) were extracted with 2 M KCl (1:20) and analyzed with a segmented flow analyzer (Technicon Autoanalyzer II system, Germany). Gas emission rate of NH_3 was measured daily during the first 2 weeks. It was then measured 3–4 times per week thereafter using detector tubes (DT) method (Sasaki et al., 2006; Kuroda et al., 2015). The Gastec detector tube system is comprised of a handheld Gastec air sampling pump and Gastec detector tube. The mechanism of the method is that ammonia concentration can be measured through color changes of chemical granules (pink into yellow) in the detector tube (10–50 ppm; 50–500 ppm; 500–1000 ppm) due to air (NH_3) suction by the hand-pump (GASTEC-Kitagawa, AP-20, Japan). Air suction/sampling was continued for one minute with a syringe-type vacuum pump (using 100 cc) fitted with a detector tube. The initial stage and the final stage of the composting solid samples were analyzed for pH, EC, TN, TC and heavy metals.

Phytotoxicity analysis was performed to assess the toxicity and maturity of the composted manure through seed germination using the filter paper method. Briefly, the filter paper was wetted with extracts of final composted manure prepared with double distilled water (water to solid ratio of 10:1). Phytotoxicity was evaluated based on germination index (GI) result obtained from germination rate and root length (Kim et al., 2017) using three crops: chrysanthemum (*Chrysanthemum indicum* L.), carrot (*Daucus carota*), and cabbage (*Brassica rapa*). Thirty seeds of each crop species were placed in sterilized Petri dishes (9 cm in diameter) lined with a double layer of wetted Whatman filter No. 1 filter discs and incubated for 5 days in dark condition. All data are reported in the present study are the means of three replicates (n = 3).

3. Results and discussion

3.1. Characterization of Hanwoo manure and sawdust mixtures

Physico-chemical compositions of Hanwoo manure in two different regions were analyzed using different parameters. They are summarized in Table 1. The pH value of Hanwoo manure was 7.54 in Pyeongchang and 7.94 in Goechang. EC (ds/m) of Hanwoo manure was 0.384 in Pyeongchang and 0.316 in in Goechang. Several authors have reported that cattle manure pH is in the range of 6.7–7.5 (Bhat et al.,