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Using cow dung and spent coffee grounds to enhance the two-stage co-composting of green waste

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ABSTRACT

The objective of this study was to determine the effects of cow dung (CD) (at 0%, 20%, and 35%) and/or spent coffee grounds (SCGs) (at 0%, 30%, and 45%) as amendments in the two-stage co-composting of green waste (GW); the percentages refer to grams of amendment per 100 g of GW based on dry weights. The combined addition of CD and SCGs improved the conditions during co-composting and the quality of the compost product in terms of composting temperature; particle-size distribution; mechanical properties; nitrogen changes; low-molecular weight compounds; humic substances; the degradation of lignin, cellulose, and hemicellulose; enzyme activities; the contents of total Kjeldahl nitrogen, total phosphorus, and total potassium; and the toxicity to germinating seeds. The combined addition of 20% CD and 45% SCGs to GW resulted in the production of the highest quality compost product and did so in only 21 days.

1. Introduction

Solid waste management is a major challenge worldwide due to the rise in population and industrialization, leading to larger amount of solid wastes being generated (Wu et al., 2014). For example, the disposal of green waste (GW) has become an increasing global problem but could be solved by composting (Zhang and Sun, 2014; Caceres et al., 2016). Composting is an environmentally friendly process involving the destruction of pathogens and the recycling of nutrients to generate a final stable product that can be used as a soil conditioner or fertilizer (Rawoteea et al., 2017). In China, composting is now commonly used to reduce the amounts of GW that are otherwise sent to landfills or to incinerators. However, traditional composting methods may require months or years to generate a mature compost from GW, because GW has a relatively high total organic carbon (TOC) content and a relatively low total Kjeldahl nitrogen (TKN) content. The cellulose, lignin, and other polymers in GW also inhibit biodegradation (Gabhane et al., 2012; Karnchanawong et al., 2017).

Many kinds of amendments have been studied in GW composting, and these include fish pond sediment, rock phosphate, spent mushroom compost, and biochar (Zhang and Sun, 2014, 2017). These amendments tend to improve the C/N ratio and porosity during composting. Another option is co-composting, i.e., the combination of different organic wastes so as to achieve suitable composting parameters before the start of composting (Zhang and Sun, 2014). In addition to providing a suitable C/N ratio, high porosity, and a large active biomass, co-composting could simultaneously dispose of two or more kinds of solid waste. In this study, a two-stage co-composting method was used. Two-stage co-composting includes a primary composting (PC) and a secondary composting (SC) as described by Zhang and Sun (2014). The GW is rapidly degraded during the PC and more slowly degraded during the SC. Because high composting temperatures (50–60 °C or even higher) can be attained twice and because the thermophilic period can last for a relatively long time, lignocellulosic GW is more effectively degraded with two-stage co-composting system than with traditional composting (Zhang et al., 2013). Therefore, two-stage co-composting can generate a better product and in a shorter time than traditional composting (Zhang and Sun, 2017).

The present research involves the two-stage co-composting of GW with cow dung (CD) and/or spent coffee grounds (SCGs). Many reports about composting indicate that CD addition can accelerate compost maturity and also improve the physicochemical properties and the nutrient content of the compost product. For example, CD can increase the water-holding capacity (WHC) of the composting mass and the amount of available water in the compost product (Caceres et al., 2016). The addition of CD (dairy manure) to sugarcane pressmud enhanced N transformations and reduced the emission and loss of gaseous N during composting (Li et al., 2016). Previous research indicated that addition of CD to composting mixtures rich in lignocellulosic residues accelerated the degradation of cellulose and hemicellulose (Monica et al., 2014). Addition of CD can introduce a different and diverse microbial community and enzymes into the composting materials,

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which can enhance the degradation rate (Shemekite et al., 2014; Karak et al., 2017). The −OH and −COOH groups in CD also bind to heavy metal ions to form insoluble and immobile complexes, which reduce the concentration of free heavy metals and the associated environmental risk (Hazarika et al., 2017). Moreover, CD contains nutrients that can increase the nutritional value of the compost for plants (Costa et al., 2016).

Coffee is the leading world commodity after crude oil, and the coffee industry generates substantial quantities of organic waste (Mussatto et al., 2011). About 6 million tons of SCGs, the by-product obtained after water extraction of roasted coffee beans, are produced per year worldwide (Hardgrove and Livesley, 2016). Because they contain polyphenols, minerals, and polysaccharides, SCGs have been studied as animal feeds and farm fertilizers. SCGs have also been studied as an inexpensive and easily available amendment to improve the composting process and to enhance the quality of the compost product (Murthy and Naidu, 2012). When added at the start of composting, SCGs can provide enough mannose, galactose, arabinose, glucose, protein, calcium, and phosphorus to support microbial activity and enzyme production (such as pectinase, tannase, and caffeinase), and to therefore enhance the degradation of organic wastes and reduce the composting period (Murthy and Naidu, 2012; Wu, 2015). Moreover, SCGs are regarded as an important source of N to reduce N gaseous loss and increase the N content in the compost product (Cruz et al., 2012). Because they contain chlorogenic acid and its derivatives, SCGs are often acidic, and SCGs addition can reduce the pH during composting and reduce the pH of the final compost (Mussatto et al., 2011). SCGs can also act as natural herbicides that eliminate weed seeds during composting (Low et al., 2015).

The effects of CD and/or SCG addition on GW composting have not been previously evaluated. This study tested the hypothesis that the two-stage co-composting of GW with the combined addition of CD and SCGs as composting amendments will shorten the composting period and produce a high quality compost. Therefore, the objectives of this research were to determine: (1) how addition of various quantities and combinations of CD and SCGs affects the physical and chemical properties during the two-stage co-composting of GW; (2) how these amendments affect the quality of the final compost; and (3) the optimal combination of CD and SCGs for the two-stage co-composting of GW. This research will help in the development of methods to transform GW into a compost product that is useful as a soil amendment or fertilizer.

2. Materials and methods

2.1. Composting material preparation

GW, which was the main composting material in the current study, consisted of fallen leaves and branch cuttings collected during urban landscape maintenance in Beijing in the spring of 2017. The GW was cut into 1-cm-long pieces before composting to support a favourable composting environment and to ensure homogeneous conditions during composting. Fresh CD was obtained from the Hebei Baotian Fertilizer Co. Ltd. (Hebei, China). SCGs were purchased from the Foshan Technology Development Co. Ltd. (Guangdong, China). Urea, which was obtained from the Beijing Jingpuyuan Biological Engineering Co. Ltd. (Beijing China), was also added before composting to adjust the initial C/N ratio. A microbial inoculum, including *Trichoderma* spp. inoculum (60%, v/v) and *Phanerochaete chrysosporium* Burdsall inoculum (40%, v/v), was prepared as described by Wei et al. (2007). The main properties of the raw materials are shown in Table 1. The determination methods are described in Section 2.4.

2.2. Composting procedures

The initial quantity of GW (dry weight) was the same in all treatments, and the quantities of CD and/or SCGs added in the nine treatments were calculated according to "percentages" indicated by an orthogonal design (Table 2); the percentages refer to grams of amendment per 100 g of GW based on dry weights. Before the start of the experiment, all parameters were adjusted to the optimal conditions for composting. First, different quantities of CD and/or SCGs were evenly mixed into the GW to form nine combinations (i.e., nine treatments) of GW, CD, and SCGs (Table 2). Then, the initial C/N ratio of the composting mixture was adjusted to 25–30 by the addition of urea (2.4 kg per 100 kg of GW dry weight), and the moisture content (60–70%, w/w) was controlled by adding water (Zhang et al., 2013). Throughout the composting, water was added to the mixtures whenever the water content dropped below 60%; water content was determined daily with an SK-100 moisture meter (Tokyo, Japan). Finally, an equal amount of microbial inoculum (5 ml per 1 kg of GW dry weight) was evenly sprayed on each composting mixture (Zhang et al., 2013).

As noted in the Introduction, the two-stage co-composting method used in this study involved a PC and a SC. At the beginning of the PC (day 0), the nine mixtures were added to digester cells. These cells, which were made by the Beijing Jingpuyuan Biological Engineering Co. Ltd. (Beijing, China), were non-covered cement containers (6 m long, 2 m wide, and 1.5 m high) with an automatic compost-turning and -watering system. Each treatment was represented by three replicate digester cells. The composting mixtures were turned for 40 min (40 r/min) every day by the automatic system to ensure adequate aeration and to breakup lumps. When the composting temperatures of all treatments dropped to 35–45 °C (this occurred on day 6), the PC was considered complete. At the beginning of the SC (day 6), the mixture was removed from each digester cell with a mini-excavator (model DLS830-9B; Shandong, China) and was placed in three open windrows (three windrows per digester cell). Each composting windrow had a trapezoidal cross-section and was 1.5 m wide × 2.0 m long × 1.0 m high. The windrows were turned over every 3 days with a mini-excavator to provide adequate aeration of the mixtures. The two-stage co-composting process was considered complete when the temperature of the windrow was stable and similar to that of the surrounding environment.

2.3. Sampling

The composting samples were collected while the mixtures were turned on day 0, 2, 4, 6, 11, 13, 21, 24, 28, and 30. Three subsamples were removed from the top, middle, and bottom of each digester cell or windrow using the method of quartering. The three 200-g samples were combined into one composite sample, which was then divided into three parts. The first part was air-dried, the second part was oven-dried at 65 °C, and the third part was not dried. All dried samples were ground to pass through 0.25- and 0.10-mm sieves. The three kinds of samples were stored in re-sealable plastic bags in a refrigerator at 4 °C. The air-dried samples were used for determination of physical properties, pH, electrical conductivity (EC), TOC, TKN, total phosphorus (TP), humic substance (HS), humic acids (HA), fulvic acids (FA), and lignocelluloses. The oven-dried samples were used for determination of total potassium (TK). The non-dried samples were used to determine mechanical properties, quantities of low-molecular compounds, and enzyme activities (dehydrogenase, cellulase, amylase, protease, phosphatase), and were also used for a seed germination test.

Temperatures in the upper, middle, and lower layers of the composting mixtures were determined daily during the entire composting process using a self-made temperature sensor with a temperature dial and 1-m-long rod. The three readings per composting mixture were averaged. Ambient temperature was also recorded.

2.4. Analytical procedures

2.4.1. Physical analysis

WHC and total porosity (TPS) were determined in the initial