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Short Communication

Effect of composting and vermicomposting on properties of particle size fractions

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HIGHLIGHTS

- Distribution and agrochemical properties of size fractions were determined.
- Compost based on kitchen and paper waste was the finest among monitored composts.
- Vermicompost was the finer and more homogeneous compared to classical compost.
- Compost particles less than 5 mm exhibited the best agricultural potential.
- Agrochemical properties of the finest vermicompost exceeded the classical compost.

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ABSTRACT

The objectives of the study were to compare the effects of the composting and the vermicomposting processes on the distribution of particles into three size fractions, and to assess the agrochemical properties of the size fractions of the composts and the vermicomposts. Three different mixtures of biowaste were subjected to two thermophilic pre-composting, and then the mixtures were subsequently subjected to 5 months composting and vermicomposting under laboratory conditions. Vermicomposting was able to achieve the finer and more homogeneous final product compared to composting. For compost, the highest portion of the finest fraction was achieved from products which originated from kitchen waste containing used paper, followed by digestate with straw, and finally sewage sludge with garden biowaste. In most cases, compost particles which were less than 5 mm exhibited the better agricultural potential than coarser compost. However, agrochemical properties of the finest vermicompost exceeded classical compost.

1. Introduction

Composting and vermicomposting are widely used for transforming organic wastes into useful soil amendments. Classical composting is defined as the controlled aerobic conversion of raw materials. Vermicomposting involves the bio-oxidation and stabilization of organic materials by the joint action of earthworms and microorganisms. Although it is the microorganisms which biochemically degrade the organic matter, earthworms are the crucial drivers of the process as they promote aeration conditions and fragment the substrate, thereby drastically increasing the microbial activity (Dominguez and Edwards, 2011).

A suitable particle size fraction and shape of particles are important in terms of operational cost for sieving and for the effect of that compost fraction in soil (Wang and Ai, 2016). Large particles have a smaller total surface area, and are therefore less accessible to microbes than the finer particles (Verma and Marschner, 2013). It has been shown that finer composts release more N and P than coarse compost (Duong et al., 2012). This indicates that in general the quality of the vermicompost is better than for compost (Sinha et al., 2010). However, scientific documentation of compost and vermicompost composed of identical particle size fractions coming from various feedstocks is scarce.

The aim of this study was to assess and compare: (i) the effect of composting and vermicomposting processes on the distribution of particles into size fractions; (ii) the agrochemical properties of size fractions from composts and vermicomposts originating from various feedstocks.

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2. Methods

2.1. Feedstock and its pre-treatment

Six types of biowaste were used in this experiment: (1) digestate after dewatering from an agricultural biogas station, (2) wheat straw as a bulking agent, (3) kitchen waste collected from households living in an urban area, (4) old paper with a proportion of coated paper (50% by volume), newsprint (40% by volume), and cardboard (10% by volume) used as a bulking agent to improve structure, enhance aeration, and absorb excess liquids, (5) anaerobically stabilized sewage sludge obtained from a city sewage treatment plant, (6) garden biowaste mixed on the basis of a composition typical for family houses in the spring period when grass, fine stalks, branches, and rest of soil prevailed. Three different mixtures of biowaste were prepared and subjected to 2 weeks of pre-treatment consisting of thermophilic pre-composting and subsequently to either composting or vermicomposting (Table 1).

All the treatments were pre-composted in laboratory reactors of 70 L capacity, with perforated stokers enhanced by 40 mm thick foam insulation to reduce heat loss. The reactors were kept in a room with ambient air about 30 °C for 14 days. The maximum temperature of 50–60 °C depending on the type of biowaste mixture was recorded in the reactors. An active aeration device was used to push air through the composted materials from the bottom. The mixtures were batch-wise aerated for 5 min out of each half hour in volume 4 L air min^{-1}.

2.2. Composting and vermicomposting set-up

For composting and vermicomposting, a specially adapted laboratory with controlled conditions (temperature 22 °C, relative humidity 80%, ventilation for 15 min every 12 h) was used. A 13 L of aerobically pre-composted material was manually mixed with 3 L of original beef manure substrate without earthworms (for composting), or with a total 600 pieces (300 g) of earthworms belonging to *Eisenia andrei* (for vermicomposting). The mixture was placed into a plastic tray with perforated bottom, equipped with irrigation and temperature measurement devices. The tray measured 40 × 40 × 18 cm. The covered trays were put into a metal rack. Each treatment was carried out in triplication. The eventual leachate which was captured in a stainless tray was returned to the composted and vermicomposted material to achieve a closed loop. The materials were turned each month during a 5 month period. At the end of this time period the fresh composts and vermicomposts were sieved through sieves which distributed the particles into 3 size fractions: F3 > 12 mm, F2 = 12–5 mm and F1 < 5 mm. Fractions were weighed on laboratory scales and the volume was determined using the graduated cylinder. The resulting samples were dried at laboratory temperature and ground into powered form for later analyses.

2.3. Analytical methods

Measurements of pH and electrical conductivity (EC) were conducted on samples mixed with deionized water (1:10 w/v dry basis) using a WTW pH 340 i and Testo 240, respectively. The volatile solids concentration was established from ignition loss in samples maintained at 550 °C for 12 h. Organic carbon was determined by dichromate oxidation in sulfuric acid solution. Total nitrogen was determined by the Kjeldahl method using a Gerhardt analytical system Vapodest-manager device. Total element contents (P, K, Ca, and Mg) were determined in the digests obtained by pressurized wet-ashing (HNO_3 + HCl + HF) with microwave heating using an Ethos 1 system (MLS GmbH, Germany). The contents of ammonium nitrogen ($N\text{-}NH_4^+$), nitrate nitrogen ($N\text{-}NO_3^-$), and dissolved organic carbon (DOC), and the available portions of P, K, and Mg were determined in CAT solution (0.01 mol l^{-1} $CaCl_2$ and 0.002 mol l^{-1} diethylene triamine pentaacetic acid (DTPA)) at the rate of 1:10 (w/v) according to the International BSI Standard EN 13651. The $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, and DOC contents in the extracts were measured colorimetrically using the SKALAR SANPLUS SYSTEM®. The element concentrations were determined using inductively coupled plasma optical emission spectrometry (ICP-OES, VARIAN VistaPro, Varian, Australia) with axial plasma configuration.

2.4. Statistical analyses

All statistical analyses were performed using the STATISTICA 9.0 software (StatSoft, Tulsa). One-way analysis of variance (ANOVA) using a 95% confidence level, followed by Tukey's test, was used.

Table 1
Proportion of feedstock in the treatments (in vol%) and type of processing.

Treatment	Feedstock (% by volume)	Type of processing
I	Digestate (50) + straw (50)	Composting
II	Digestate (50) + straw (50)	Vermicomposting
III	Kitchen waste (50) + paper (50)	Composting
IV	Kitchen waste (50) + paper (50)	Vermicomposting
V	Sewage sludge (50) + garden biowaste (50)	Composting
VI	Sewage sludge (50) + garden biowaste (50)	Vermicomposting

3. Results and discussion

3.1. Proportion of particle size fractions

The proportion of three particle size fractions in the composts and vermicomposts after 5 months of exposure to the composting and vermicomposting processes is illustrated in Fig. 1. Clear differences were found between composts and vermicomposts. Particles smaller than 5 mm represented almost 100% of the resulting fresh vermicomposts produced. The influence of earthworms on the efficiency of biological waste treatment was significant. This is consistent with a study which dealt with the particle size analysis of composts and vermicomposts based on biosolids which originated from different production systems (Ndegwa and Thompson, 2001). Unlike our approach with size characteristic of fresh matter, their samples were dried at first in an oven at 100 °C for 24 h and were then broken into individual grains by hand. A set of seven-sieves was selected with screen-openings of 6.35, 3.36, 1.68, 1.19, 0.84, 0.42, and 0.25 mm, respectively. The majority proportion of the vermicompost particles was found in the 0.84 and 0.42 mm fine fractions. Conversely, the compost contained mainly coarse

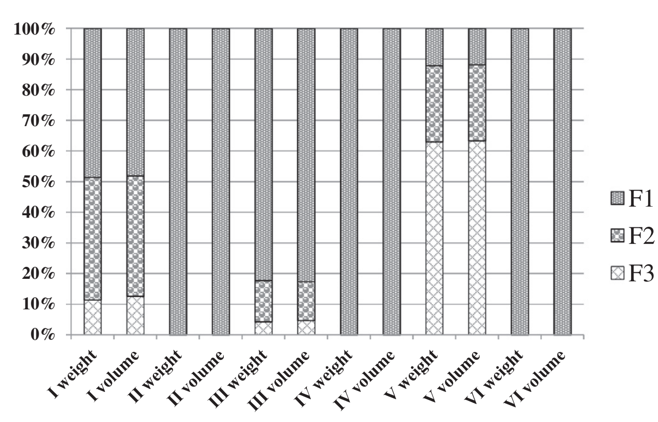

Fig. 1. The relative proportion of the F3, F2, and F1 particle size fractions in composts and vermicomposts in weight and volume %.