



Composting of bio-waste, aerobic and anaerobic sludges – Effect of feedstock on the process and quality of compost

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ABSTRACT

In-vessel composting of three stocks with originally different degree of organic matter degradation was conducted for: (1) kitchen source-separated bio-waste (BW), (2) aerobic (AS) as well as (3) anaerobic sludges (AnS) from municipal wastewater treatment plant. Composting experiment lasted over a year. The highest activity of the process was in the BW compost. It was implied by the highest temperature, CO₂ release, ammonification and nitrification, intensive accumulation and removal of low-weight carboxylic acids (water- and NaOH-extractable). Between the sludges higher mineralization and CO₂ release was in AnS, while ammonification and nitrification were higher in AS compost; no significant difference between sludge composts was noticed for dynamics of pH, conductivity, concentrations of LWCA, and some nutrient compounds and heavy metals. Nitrogen content of the final compost increased in BW, but decreased in AS and AnS. Phytotoxicity of *Lepidium sativum* was eliminated faster in sludge composts compared to BW compost.

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1. Introduction

Urban organic waste (food scrapes, green and park wastes, sewage sludge, etc.) is a very unstable quickly biodegrading waste fraction. Its treatment is challenging in terms of avoiding odour and pathogen nuisance. On the other hand it has high potential as soil amendment. According to Eurostat the estimated generation rate of animal and vegetable agricultural waste in EU countries in 2006 was 95 Mt. The estimated amount of animal waste generated from food production was 13 Mt, the amount of sewage sludge arising was about 17 Mt. Composting is regarded as a suitable way for recycling such type of waste because it helps to solve the problem of their disposal, reduce emissions of greenhouse gas, and also result in a useful soil improving agent – compost. This end product can be used for agricultural purposes to improve soils, and especially to recover the degraded soils in semiarid zones, because its incorporation in soil in suitable conditions increases fertility (Banegas et al., 2007).

According to the Green Paper on the Management of Bio-waste in EU (Commission of the European Communities, 2008) the total production of compost in 2005 in EU countries was 13.2 Mt. Most of it was produced from bio-waste (4.8 Mt) and green waste (5.7 Mt), the rest from sewage sludge (1.4 Mt) and mixed waste (1.4 Mt). The potential of compost production from most valuable

inputs (bio-waste and green waste) is estimated at 35–40 Mt, which means that high quality compost can significantly improve quality of European soils. However, production of high quality compost is not necessarily the aim of waste-processing companies. As on one hand compost production process is financed by the gate fees for the waste, so the commercial success of compost production depends very little on the sale of the final product. On the other hand, in most European countries the quality of composts is defined by low contents of pollutants particularly heavy metals, organic pollutants, impurities (Binner et al., 2008), with no standards set for the quality as soil improver. Overall, bio-waste as source of nutrients is highly under used.

Although composting is a widely used process, there are still knowledge gaps in understanding it due to high variety and heterogeneity of the feedstock materials, abundance of the processing technologies, openness of the system, end product chemistry, etc. Studies have been conducted on different feedstocks like bio-waste (Pascual et al., 1997; Kirchman and Widén, 1994), aerobic and anaerobic sludges (Banegas et al., 2007; Fuentes et al., 2006; Li et al., 2001), and manures (Tiquia and Tam, 1998) with various bulking agents and additives. However, few attempts have been made to compare composting process of three most widely used feedstocks in one research to reveal effect of status of organic matter degradation on the process and on the quality of the final product. This is an important aspect because in general composting sums up to mineralization of organic matter and is highly driven by the availability of organic compounds for the microorganisms.

The aim of our research was to compare effectiveness of material stabilization during composting of three feedstocks with

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originally different status of organic matter degradation (kitchen bio-waste, aerobic and anaerobic sludges from municipal wastewater treatment plant) and assess the suitability of the final products as soil amendment.

2. Methods

2.1. Composting experiment

A laboratory trial was performed with three different feedstocks – at-source separated kitchen bio-waste (BW), aerobic sludge (AS), and de-watered municipal anaerobic sludge (AnS). Bio-waste was collected for 3 days at the food catering centre of the town of Mikkeli (Finland). It was a mixture of food leftovers and vegetable waste (i.e. salad stunts, cabbage leaves and stunts, carrot and potato peels, etc.). Aerobic sludge was de-watered product from the wastewater treatment facility in municipality of Ristiina close to Mikkeli. Anaerobic sludge was de-watered product from the third anaerobic stage after pre-treatment and aerobic treatment collected at the wastewater treatment plant in Mikkeli town. Both sludges were coming from low industrialized towns. Each feedstock was mixed with sphagnum peat as bulk material in proportion 1 + 1 (v/v). The peat was collected at local waste-processing company. Three insulated lid-covered composters (220 L, Biolan, Finland) supplied with leachate-collecting system were filled with three different feedstock-peat mixtures. Passive aeration of the composters occurred through a system of bored holes and was based on air-pressure difference between the inner and outer parts of the composter. Some characteristics of the mixtures are presented in Table 1.

The experiment lasted for 63 weeks. During this period the composting mass was mixed manually once every 2 weeks during the first 12 weeks and after that on week 16, 24 and 63. For mixing, all the material was removed from the composter into a separate container and thoroughly mixed with shovel, no water was added. After mixing, about 10 L of a composite sample was taken; one part of the sample was analyzed immediately, another part dried at 35 °C, and a third part frozen at –18 °C until processed for further analysis. After sampling, the material was put back into the composter.

Table 1

Characteristics of the materials at the beginning of composting experiment. BW = bio-waste + peat (1 + 1, v/v), AS = aerobic sludge + peat (1 + 1, v/v), and AnS = anaerobic sludge + peat (1 + 1, v/v). Mean ± SD of triplicate subsamples, except total low-weight carboxylic acids (LWCA), which are means of four replicate subsamples.

Characteristic	BW	AS	AnS
pH (compost-water mixture, 1 + 5, v/v)	4.5 ± 0.1	5.7 ± 0.0	6.4 ± 0.1
Conductivity (1 + 5, mS/cm)	0.69 ± 0.07	0.27 ± 0.02	0.88 ± 0.11
Dry matter (%)	31.4 ± 0.0	15.4 ± 0.0	16.0 ± 0.0
Ash content (%)	23.0 ± 3.3	19.2 ± 1.6	19.6 ± 0.2
Total C (%)	39.0 ± 0.6	36.5 ± 0.4	34.1 ± 0.6
Total N (%)	2.0 ± 0.1	2.4 ± 0.02	2.1 ± 0.03
C/N ratio	20	15	16
Total water-soluble LWCA ^a (mg/kg dw)	8600 ± 650	13,800 ± 800	11,200 ± 550
Total NaOH-soluble LWCA ^a (mg/kg dw)	12,300 ± 700	14,300 ± 1000	6600 ± 4600
Phytotoxicity, 48 h (% control) ^b	8.1 ± 2.1	6.6 ± 0.8	2.3 ± 1.9
Phytotoxicity, 14 days (% control) ^c	34.4 ± 9.7	56.6 ± 9.9	44.6 ± 11.1

^a Low-weight carboxylic acids.

^b Obtained after 48 h incubation of *L. sativum* in water extract of compost (1:2; v/v), control – de-ionized water.

^c Obtained after 14 days growth of *Lepidium sativum* in compost – peat-based growth medium (1:2, v/v), control – peat-based growth medium.

2.2. Monitoring and compost analysis

The process was monitored by measuring the temperature of the compost at 50 cm depth and concentrations of gases inside the composter above the mass before mixing of the composts. Gas was pumped into gas-collecting bag using silicone hose put through the hole in the lid of the composter. An infrared gas analyzer (GA94, Geotechnical Instruments) was used for analysis of oxygen, carbon dioxide and methane, and Dräger detection tubes (0.25/a and 5/a, National Dräger Inc., USA) for analysis of gaseous ammonia. The pH and conductivity of fresh compost samples were analyzed according to standard methods CEN13037 and CEN13038, respectively (European Committee for Standardization, 1999a,b). The concentration of water-soluble ammonium-, nitrate- and nitrite-nitrogen in compost-distilled water extract (1 + 5, v/v) was detected using test strips (Merckoquant ammonium test and nitrate test; Merck Chemicals, Darmstadt, Germany); detection limit for NH₄-N was 7.8 mg/L, NO₂-N 0.6 mg/L, and NO₃-N 2.3 mg/L.

Dry matter (at 105 °C, 24 h) and ash content (at 550 °C, 24 h) were measured according to the modified standard CEN13039 (European Committee for Standardization, 1999c). Based on the results of ash measurements, the mineralization rate of organic matter was calculated based on ash conservation principle. According to the principle, while organic matter degrades the absolute amount of ash does not change until formation of nitrites and nitrates as a result of nitrification. In this case absolute ash content slightly increases, but this change is negligible compared to overall ash content. Based on this assumption, mineralization rate was calculated according to the formulas:

At the start of composting :

$$M_{\text{ash}} = M_{\text{compost } 0} \times C_{\text{ash } 0} \quad \text{and} \quad M_{\text{org } 0} = M_{\text{compost } 0} - M_{\text{ash}} \quad (1)$$

After t time of composting :

$$M_{\text{compost } 0} \times C_{\text{ash } 0} / C_{\text{ash } t} \quad \text{and} \quad M_{\text{org } t} = M_{\text{compost } t} - M_{\text{ash}} \quad (2)$$

$$\text{MR} = M_{\text{org } t} / M_{\text{org } 0} \times 100, \quad (3)$$

where M_{ash} = mass of ash (kg), $M_{\text{compost } 0}$ = total mass of compost in the beginning of composting (kg), $M_{\text{compost } t}$ = total mass of compost after t time of composting (kg), $C_{\text{ash } 0}$, $t =$ percent of ash analyzed in compost mass in the beginning of composting (%), $C_{\text{ash } 0}$, $t =$ percent of ash analyzed in compost mass after t time of composting (%), $M_{\text{org } 0}$, $t =$ mass of organic matter in compost in the beginning or after t time of composting (kg), and MR = mineralization rate during t time of composting (%).

For calculations compost was weighted in the beginning of the experiment.

Concentration of macro- and microelements, and heavy metals were analyzed in compost samples taken as mentioned above after 1, 8 and 63 weeks of composting. Analyses were made at the Department of Chemistry in Jyväskylä University. Prior to the analysis the samples were dried at 35 °C for 48 h, milled and sieved through a 2 mm mesh. Carbon and nitrogen were measured with CHNOS elemental analyzer using a TCD detector after combustion at 800 °C (Elementar vario ELIII, Elementar Analysensystem GmbH, Germany). Macro- and microelements and heavy metals were extracted with aqua-regia-water mixture (1:1, v/v) and ultrasound assistance, and analyzed with ICP-AES (Model 2000, PerkinElmer, USA) according to Väisänen et al. (2002). Samples were analyzed in triplicates.

Low-weight carboxylic acids (LWCA) were analyzed in compost-H₂O and compost NaOH (0.1 M) extracts according to modified method given in Alén et al. (1985). For detailed description of the sample's pre-treatment and method modifications see

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