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Maturity indices in co-composting of chicken manure and sawdust with biochar

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HIGHLIGHTS

- Maturity indices were evaluated while co-composting feedstocks with different biochars.
- Except C/N, other parameters were found to be suitable as compost maturity indices.
- All three biochars were found to decrease NH_3 emission from finished compost.

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ABSTRACT

Several maturity indices were evaluated for in-vessel co-composting of chicken manure and pine sawdust with three different biochars. All the seven mixtures (piles) contained chicken manure and sawdust. Six of these piles contained biochar; each biochar was added at two rates, 5% and 10% wet weight. The maturity of composts was assessed by C/N, dissolved organic carbon (DOC), seed germination, NO_3^--N/NH_4^+-N, and the Solvita test. The C/N values of finished composts were from 31.5 to 35.7, which were much higher than the optimum value of 21 for matured compost. Nevertheless, the rest of the parameters indicated that the composts were matured. The C/N values were high because of the high amount of recalcitrant carbon present in the feedstocks: biochar and sawdust. Biochar treated piles showed higher respiration as well as decomposition of DOC indicating higher microbial activity. Use of biochar in composting may reduce NH_3 emission and nitrate leaching.

1. Introduction

The aim of composting is to convert solid organic wastes into nutrient rich soil conditioner and organic fertilizer that has reduced odor, phytotoxic chemicals, weed seeds and pathogens. Composting is a biochemical process of decomposition of organic matter (OM). Heat, CO_2, and nutrients are released, and humified OM is formed during this process. Integrated activity of numerous types of indigenous microorganisms is the main factor driving decomposition of OM. The microorganisms are active only at the solid–water interface.

Biodegradation performance of aerobic composting at any time depends on physical (temperature, moisture, size and degree of mixing of feedstocks), chemical (O_2 from air) and nutritional (bioavailable N, P, K and C in the feedstock) conditions (Golueke, 1991). The microbial activity produces gradual changes in physical e.g. temperature, chemical e.g. C/N, and/or biological parameters e.g. seed germination. Hence these parameters may be used as maturity indices that reveal progress of composting. A compost is considered 'stable' when microbial activity of an end product reduces to an insignificant level; 'matured' when phytotoxins are reduced to a safer level; and 'finished' when both stability and maturity are reached. It should be noted, however, that the terms 'stability' and 'maturity' are used interchangeably in the literature.

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Temperature (USCC, 2002), C/N (USCC, 2002), DOC (Bernal et al., 1998; Chefetz et al., 1998), NH_4^+-N/NO_3^--N ratio (Sánchez-Monedero et al., 2001) (USCC, 2002) are pre-established stability indices of composting. While, seed germination (Zucconi et al., 1981) and Solvita compost emission tests (USCC, 2002) are pre-established indices of maturity.

Sawdust contains a significant amount of lignin, a recalcitrant organic polymer that also inhibits microbial access to cellulose and hemi-cellulose. Pine softwood contains ~30% lignin (Sannigrahi et al., 2008).

Biochar contains a high amount of recalcitrant aromatic C (Lehmann et al., 2009) however, paradoxically microorganisms proliferate on its surface (Ogawa, 1994) and in its pores (Thies and Rillig, 2009). The aromatic C in poultry litter biochar is approximately 55% (McBeath and Smernik, 2009), whereas it is 74% or higher in plant based feedstocks (McBeath and Smernik, 2009). Only a few groups of microorganisms e.g. micro-fungi: brown-rot fungi and bacteria: actinomycetes or myxobacteria can modify and partially degrade softwood respectively (Tuomela et al., 2000). Lignin decomposition is therefore a slow process. The aromatic C of biochar is probably more recalcitrant than lignin as biochar is known to persist in soils from hundreds to thousands of years (Preston and Schmidt, 2006).

We assumed that, co-composting of a feedstock mixture that had a high ratio of sawdust as well as biochar might result in a higher percentage of C due to recalcitrant C present in both, especially if the period of composting is relatively short so that decomposition of lignin remains largely incomplete. This could affect the C/N index. Moreover, the positive effect of biochar on microbial population (and activity) might influence other maturity indices. There are only a small number of studies published where biochar was co-composted, but none of these specifically focused on biochar's effect on maturity indices. The objectives of this study were to identify conventional maturity indices suitable for composting mixtures containing sawdust and biochar, and to investigate the influence of biochar on these parameters.

2. Methods

2.1. Composting

Three different biochars, made from macadamia nut shell (*bc*MS), hardwood shavings (*bc*WS) and chicken litter (based on bed of wood shavings, (*bc*CL), were used as feedstocks for composting (Table 1 and Table 2). The mixing of feedstocks was governed by biochar% and C/N value. The feedstocks and moisture were blended in a cement mixer that was lined with a strong polythene bag. All seven feedstock mixtures (piles) contained chicken manure and pine softwood sawdust (sawdust). The control pile contained no biochar. The other six piles were treated with biochar at two rates: 5% and 10% wet weight. Accordingly, the piles were labeled as *pile*CNT, *pile*MS5, *pile*MS10, *pile*WS5, *pile*WS10, *pile*CL5, and *pile*CL10. The C/N ratio of the piles on day 0 ranged from 24.4 to 29.6 (Table 3). The piles (~125 L) were composted in spherical plastic bins (~153 L) (Fig. 1). The bins were placed in an automated greenhouse that maintained temperature between 20 °C and 50 °C. The temperature at the center of each composting pile was measured every 2 h using a digital temperature logger. The temperature in the greenhouse was also recorded. The bins had 10 cm inlet pipes for passive air supply to aid microbial respiration. Each bin was fitted with an aeration system for additional air supply at a rate of 0.028 L min^{-1} kg^{-1} DM that was low thus minimized loss of N as NH_3 from pile (De Guardia et al., 2008). The piles were turned by rolling the bin in the direction of three axes 45° apart (Fig. 1). This further improved air supply by loosening up the materials and also aided homogenization particularly before sampling. The bins were rolled twice in the first week and then once every week. Previously, three pilot trials were conducted to determine the rate of rolling per week and pile moisture percentage, which would favor the composting process in CompoSpin bin (Khan et al., 2012). The rolling was stopped after 12th week when it was noticed that the pile temperature slowly decreased to ambient temperature level, and also the former temperature was not rising more than a few degrees as a response to rolling. The pile moisture was maintained between 53% and 60% during the composting period.

Sampling was carried out biweekly from four locations in a pile after rolling the bins. These were mixed to make a composite sample. Rolling, followed by mixing, was carried out to ensure representative sampling. Finally, a set of six (composite) samples from days 0, 14, 28, 56, 84 and 126 across four stages (initial, thermophilic, end active and mature) of the composting process were selected for analysis. To meet various analytical needs, feedstocks and pile samples were air dried, oven dried or left as it was (i.e. wet); then stored at room temperature, 4 °C or −18 °C.

2.2. Seed germination test

For germination phytotoxicity test, eight seeds of Garden Cress (*Lepidium sativa*) were incubated with 1 mL of compost extract (1:10, dw:v) of water at 25 °C in the dark for 72 h (adapted from Zucconi et al. (1981)) on sterilized cellulose filter paper (Whatman No. 1) placed in a petri dish sealed with parafilm. Similarly, a control was prepared with water. Each treatment had three replications. Root length was determined by line intercept method (Tennant, 1975) after placing seedlings on a 1 mm grid printed against dark grey background. The line intercept method was used because it is faster than direct length measurement. Seed germination index (GI) was calculated from the relative seed germination % and relative root length % (Tiquia and Tam, 1998). For relative germination%, both the dead and living seedlings that germinated were counted. Similarly, for relative root length%, both the dead and living roots were measured.

2.3. Solvita compost emission tests

Solvita® compost emission test was conducted in a closed Solvita jar using gel probes of CO_2 and NH_3 for a 4 h period at room temperature on wet samples from days 84 and 126 (Woodsend, 2009). CO_2 and NH_3 emissions over a 4 h period were calculated from an exponential equations $y = 20.999e^{-4.805x}$ and $y = 78593.599e^{-1.145x}$, respectively, where x represents corresponding color index. The

Table 1
Properties of compost feedstocks.

Feedstock	pH	EC (dS m^{-1})	C%	N%	P%	K%	S%	DOC (g kg^{-1})
Chicken manure	7.99	7.49	33.04	3.73	2.02	2.69	0.58	39.73
Sawdust	4.13	0.23	49.77	0.06	<0.01	0.02	0.01	No data
*bc*MS	10.29	0.17	74.72	0.66	0.09	1.02	0.05	0.55
*bc*WS	3.05	8.22	67.07	0.25	<0.01	<0.01	<0.01	4.23
*bc*CL	7.83	4.80	33.20	3.84	1.19	2.85	0.31	1.35