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Evolution of non-dissolved particulate organic matter during composting of sludge with straw

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Abstract

Long term composting induces loss of C and organic matter stabilisation. These two processes may have opposite effects on long term carbon storage in soils. To check whether raw materials should be composted or not before being spread on the soil, changes in particle size fractions were quantified during composting of 9 tons of sewage sludge and straw. Both the mass of the fine fraction (<2 μm) and the amount of carbon contained in it increased after seven months, respectively, +37% and +43%. The fine fraction contributes to carbon sequestration. A literature review supported the assumption that composting should increase long term C storage. Nevertheless, soil texture or agricultural practices modify the behaviour of this fraction. Thus, the fractionation method used for soils is relevant to predict the effect of composting as a mitigation option in greenhouse gas reduction strategies, but is not sufficient in itself.

Keywords: Compost; Carbon sequestration; Particle size; Fractionation

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1. Introduction

The concept of particle size fractionation has proved its relevance in soil studies to assess carbon sequestration. It has received little attention in compost studies, despite the known contribution of composting to organic matter stabilisation before agronomic or horticultural use. The potential of compost applications to increase carbon storage in soils is well established, but the specific effect of the composting process on the stabilisation rate of carbon in soils is poorly known, while it is clear that much of the carbon is lost during composting. Until now, it is not clear whether it is better for long term carbon storage to spread raw materials directly, i.e. to add more carbon to soils, or to compost these materials before spreading, i.e. to add more stable organic matter.

The use of this concept to understand and model organic matter behaviour in soils appeared in the late 1980s (McKeague et al., 1986; Balesdent et al., 1988; Leinweber and Reuter, 1992; Christensen, 2001; Manlay et al., 2007). Much literature has shown that fine size fractions (<200 μm), and especially the so-called clay-like fraction (<2 μm), have a crucial impact on carbon stabilisation processes in soils (Balesdent, 1996; Balesdent et al., 2000; Leifeld et al., 2001). Denef et al. (2007) showed that the amount of microaggregate-associated carbon (53–250 μm or <53 μm) can be used to monitor carbon sequestration better than total soil organic carbon. Christensen (1992) stressed the importance of physical fractionation to assess the turnover of soil organic matter. Knowledge of physical

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fractions, therefore, becomes a prerequisite for understanding the chemical reactivity and inherent fertility of soils, and for predicting the fate of mineral fertilizers, animal manure, and crop residues added to soil. The concept of particle fractions is also relevant for heavy metal issues (Besnard et al., 2001; Veeken and Hamelers, 2002). Finally, Derrien et al. (2006) and Lützow et al. (2006) showed that, to study the mineralisation of carbohydrates, it was more relevant than that of chemical availability, because of the important role of physical protection of organic matter.

Despite its recognised importance in soil studies and the common use of composts as fertilisers or soil amendments, the concept of particle size fractionation has not received much attention in compost studies. For instance, Baffi et al. (2007) suggested characterising the biological stability of compost using various methods (respiration, humification, thermostability), but they did not consider the long term behaviour of composts in soils. Furthermore, most literature on composting deals with coarse particle dynamics, because of its effect on compost aeration and physical accessibility of organic matter (Haug, 1993; Carmona et al., 2003; Lhadi et al., 2006; Benito et al., 2006; Bueno et al., 2007). According to the available literature, only Aoyama (1985, 1991) and Dur et al. (2006) considered fine particles in composts from a qualitative point of view. Aoyama analysed the composition of the fine fraction of composts, but not the effect of the composting process on its evolution, while Dur et al. did not consider the coarse fraction in their study.

The work reported here has two objectives: (i) to check if the composting process can increase the fine size fraction and (ii) to investigate whether or not raw materials should be composted in order to increase their effect on long term carbon storage, in the light of the available literature.

2. Methods

2.1. Experimental design

The experiment was done at the composting facility of Quatre-Vaulx Jardin (Corseul, Côtes d'Armor, France). Sludge came from a storage tank of the rural wastewater treatment plant of Ecouflant (Maine-et-Loire, France) based on a conventional activated sludge system. The sludge was only pressed prior to composting using a filter band to reach 15% dry matter. Wheat straw came from a farm near Corseul.

Substrate mixing and the composting process were carried out as described by Pourcher et al. (2005). Briefly, a total of 8.1 tonnes of pressed sludge was mixed with 1.4 tonnes of straw in a 1:0.17 ratio on a wet weight basis, in a weighing-mixing trailer. The resulting mixture was spread in a box to expand it and ensure natural aeration. The final shape of the heap was adjusted to a trapezoidal geometry, 1.2 m high with bases of 4.85 and 3.85 m long, and 3.90 m wide.

The pile temperature profile was recorded by means of thermocouple probes inserted in three areas of the pile: within the surface layer (0.1 m below the surface); at 0.4 m below the surface; and 0.2 m above the ground. The probes were connected to a datalogger, recording at 1 h intervals (Pourcher et al, 2005).

The composting period lasted seven months. The initial time is designated t_0, the turning dates by t_1 (27 days), t_2 (48 days), t_3 (76 days), t_4 (111 days), and the final date is t_5 (202 days). These day numbers are only indicative, because reproducibility of this experiment would need to also reproduce two factors that influence the transformation rate but could not be controlled here: outside weather and pore size distribution within the heap.

Sampling was carried out on the mixture during mixing in the mixer-weigher. Around 100 kg were collected at different times during the mixing process, then mixed and repeatedly divided in half, until homogeneous samples were obtained. Four replicates, of approx. 1 kg each, were used for chemical analysis. For the particle size study, samples were only taken at t_0, t_1, t_3, and t_5 in triplicate, to limit experimental costs.

2.2. Particulate organic matter analysis

Particle size fractionation was carried out according to the method of Balesdent et al. (1988) and Ducaroir et al. (1990), slightly modified as described by Ablain (2002). Briefly, a suspension (1:2.5 dry sample to water ratio) was shaken for 16 h, then sieved successively at 200, 100, and 50 μm under flowing water. The total water volume used for sieving was kept below 2 l by recycling used water. Light-weight organic debris of these fractions (200–2000, 100–200, 50–100 μm) was separated from the heavier components by flotation, resulting in six fractions in the size grade 50–2000 μm. The suspension of particles <50 μm was treated by ultrasound for 10 min to disrupt persisting microaggregates (Anderson et al., 1981; Leifeld et al., 2001).

Residual coarse and fine particles were separated on a 20 μm sieve, retaining the coarse silt-like fraction (20–50 μm). The clay-like fraction (Clf, <2 μm) and the fine silt-like fraction (2–20 μm) were separated by sedimentation according to Stokes' law (Balesdent et al., 1988), resulting in three fractions in the size grade 0–50 μm. The Clf was centrifuged at 10,000 rpm for 10 min, the supernatant being recycled for sieving, and the pellets being dried.

Fractions >20 μm were oven-dried and then weighed. Fractions <20 μm were freeze-dried. All the fractions were weighed and ground to pass a 200 μm sieve before carbon and nitrogen analysis.

2.3. Chemical and biochemical analysis

Chemical analysis of the composts was performed using standard procedures (Pourcher et al., 2005). Total nitrogen and carbon of the raw composts were determined with a CHN analyser (FLASH EA 1112, Thermo Finnigan) from an aliquot of the samples after drying and grinding with a marble grinder. Total nitrogen and carbon of the organic