Geophysical Research Abstracts, Vol. 7, 09606, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09606

Evaluating the efficiency of the composting process: a comparison of different parameters.

G. Gigliotti (1), F. Valentini (2), F.G. Erriquens (1) and D. Said-Pullicino(1)

(1) Department of Agricultural and Environmental Science, Faculty of Agriculture, University of Perugia, Italy (gigliott@unipg.it)

(2) GESENU S.p.A., Perugia, Italy.

Introduction

Composting is one of the technologies of integrated waste management strategies, used for the recycling of organic materials into a useful product. It can be defined as the biological decomposition of waste organic matter into a humus-like, stable product under controlled, aerobic conditions. The term "controlled" indicates that the process is managed and optimized to decompose potentially putrescible organic matter into a stable product that may be used for soil improvements, and to disinfect organic wastes from pathogens and weed seeds (Epstein E., 1997). The application of compost to agricultural land is a practice which is gaining importance particularly due to its beneficial properties in improving soil fertility and plant growth, and reducing the potential of erosion and desertification.

Like any biological process, an effective and efficient transformation of fresh organic matter can only be achieved when the ideal environmental conditions required for the establishment of the microbial population are provided. For this reason, the major parameters on which the process depends are temperature, moisture content and oxygen availability, controlled through aeration, wetting and mixing of the feedstock respectively. However, since the process is rather complex due to the heterogeneous composition of the feedstocks, monitoring and controlling these parameters alone does not allow the prediction of the quality of the final compost. Knowledge on the changes in organic matter composition during composting is important to achieve efficient and complete transformation in the shortest time with the minimum environmental impact. Parameters that directly describe these changes are stability, the evolution of organic matter and maturity.

Stability, defined in terms of the bioavailability of organic matter, is a function of the content of labile compounds in the composting mixture as well as the oxygen demand required for aerobic metabolism (Cooperband *et al.*, 2003). Organic matter evolution refers to the decomposition of labile organic compounds and simultaneous synthesis of humic-like substances during the composting process (Adani *et al.*, 1997). Maturity is defined as the capacity of compost to support plant growth and is related to the presence of phytotoxic compounds, the oxygen demand and the evolution of organic matter (Cooperband *et al.*, 2003).

Although there are a number of studies that propose different methods for evaluating changes in these parameters during the composting process (Brewer et al., 2003; Adani et al, 1997; Chica et al., 2003), few have actually compared these methods in order to confirm their capability to evaluate the efficiency of different composting processes. In this work the changes in stability, organic matter evolution and maturity were studied through the variations in respirometric indices, composition of dissolved organic matter, humification parameters, organic matter evolution index and a seed germination index with composting time. In order to confirm the applicability of these analytical parameters to various composting scenarios, different raw material mixtures treated in two composting plants were considered.

Materials and Methods

Raw materials and composting processes

Three urban waste composts were produced mechanically under aerobic conditions by fast aerobic digestion (28 d) followed by a curing phase. Composts SCOM1 and TCOM1 were produced at a composting plant in Perugia (Italy) while SCOM2 was produced in Milan (Italy). SCOM1 and SCOM2 were produced from a standard mixture of source-separated municipal solid waste and yard trimmings, in a feedstock ratio of 50:50% and 70:30% respectively. TCOM1 was produced from an experimental feedstock composed of source-separated municipal solid waste (55%), yard trimmings (30%) and foliage residues from the tobacco agro-industry (15%). The changes in the chemical characteristics of the feedstock with composting time were studied by collecting and analysing compost samples at different times.

Chemical properties

Changes in some of the chemical properties of the feedstocks during composting were determined following standard procedures (MIPAF, 2001). Analysis involved the determination of moisture content, volatile solids, ash content, pH and electrical conductivity, total organic carbon (TOC) content by dichromate oxidation, total Kjeldahl and organic nitrogen. Total and labile polysaccharides were determined utilizing a spectrophotometric method (Lowe, 1993).

Respirometric analysis

The specific oxygen uptake rate (SOUR) was determined by measuring the rate of oxygen consumption in the liquid state for the various compost samples, and used as a measure of organic matter stability (Adani *et al.*, 2003). SOUR evaluates the maximum rate of oxygen consumption by a compost sample suspended in a nutrient solution over 24 hours, at 35˚C and pH 7. Dissolved oxygen was measured in reading cycles of 15 min followed by 15 min of aeration. Cumulative oxygen demand at 12 hours and at 20 hours (OD_{12} and OD_{20}) was calculated as the integral of the oxygen uptake over 12 and 20 hours of test, respectively.

Extraction, fractionation and characterization of dissolved organic matter

Dissolved organic matter (DOM) was obtained from composting samples (SCOM1, SCOM2 and TCOM1) by overnight extraction with deionized and degassed water (extraction ratio of 1:10 on a dry weight basis) at room temperature, followed by centrifugation and filtration of the supernatant through a 0.45μm membrane filter. Fractionation of the DOM extracts into the hydrophilic (HiDOM) and hydrophobic (HoDOM) fractions was carried out using an Amberlite XAD-8 resin (Gigliotti et al., 2002). Analysis of DOM extracts involved the determination of total dissolved organic carbon (DOC), carbon content in hydrophilic and hydrophobic fractions and dissolved organic nitrogen (DON).

Humification parameters

Humic-like substances were extracted from the compost samples as described by Ciavatta *et al*. (1990) and the total extractable carbon (TEC) determined by wet dichromate oxidation. The extracts were fractionated into humic acids (HA), fulvic acids (FA) and non-humic (NH) fraction (Ciavatta *et al.*, 1990). After purification, the carbon content of each fraction was determined. The humification parameters calculated included (i) the humification ratio (HR %) representing the (HA+FA) to TOC ratio, (ii) the degree of humification (DH %) representing the (HA+FA) to TEC ratio, and (iii) the humification index (HI) representing the NH to (HA+FA) ratio.

Organic matter evolution index (OMEI)

The OMEI was determined as described by Adani *et al*. (1997). The method is based on the treatment of samples with a sequence of non-polar solvents, followed by hot 5% sulphuric acid and cold 72% sulphuric acid. These treatments allow the removal of lipids, waxes, hemicellulose, proteins and cellulose from the humic acid fraction.

The index was determined as the ratio between carbon content in the humic fraction with (CHA2) and without (CHA1) the removal of the pseudo-humic substances, and is dependent on the degradation of coating materials associated with humic acids and the formation of new humic-like structures.

Seed germination test

The effects of compost maturity on seedling emergence were determined utilizing samples water extracts as germination media and *Lepidium sativum* L. as a test species (Zucconi *et al.*, 1985). The extracts, obtained by bringing samples water content to 85%, were filtered through a 0.45μm membrane filter and together with 3 dilutions (25, 50 and 75%) were used as the germination media. The number of germinated seeds and the primary root length were measured and expressed as a percentage of the control. Data were analyzed against the compost age and the concentration of the sample water extract in the growing media.

Results and Discussion

All the three composting processes studied showed a good efficiency in reducing feedstock oxygen demand with composting time. In fact, the SOUR values for SCOM1, SCOM2 and TCOM1 decreased by 90 %, 80 % and 93% with respect to the maximum oxygen uptake rate, by the end of the process. Among the respiration indices, the OD_{12} and OD_{20} seem to better express the changes in compost stability. This could be expected since these indices that represent the cumulative oxygen demand, have the advantage of including the aerobic degradation of the more refractory organic compounds, whereas the SOUR only gives the maximum rate of oxygen demand which generally occurs within the first 6 hours of analysis time and is only due to readily degradable compounds. All three indices used for measuring feedstock stability were well correlated ($p \leq 0.05$) with the total organic carbon to total Kjeldhal nitrogen ratio (C:N) irrespective of the composting process or feedstock composition. This was expected since the availability of carbon and nitrogen plays an important role on the microbial metabolism of organic matter (Epstein, 1997).

A highly significant, positive correlation ($p \leq 0.01$) was observed between the respiration indices and the carbon content of dissolved organic matter (DOM) and its hydrophilic fraction (HiDOM). This suggests that soluble organic compounds, particularly those forming part of the hydrophilic fraction, are easily degraded and therefore mainly responsible for the oxygen demand. The observed decrease in labile polysaccharides with increasing feedstock stability shows that these compounds are particularly prone to degradation during the process. For the same reason the ratio of hydrophobic to hydrophilic carbon content (HoDOC:HiDOC) of DOM increased with composting time and could possibly serve as a valid indicator of compost stability.

In fact, a significant negative correlation ($p \leq 0.05$) was obtained between the respiration indices and the HoDOC:HiDOC ratio, for all the feedstocks studied. This confirms that this ratio could be used to evaluate changes in stability with composting time for different feedstock compositions and composting processes. Amongst the samples analyzed, lowest values of SOUR, OD_{12} and OD_{20} were obtained for the samples having a HoDOC:HiDOC ratio greater than unity.

During composting, organic matter does not only undergo processes of degradation but is also involved in re-synthesis and polymerization reactions that result in the formation of humic-like substances. The term evolution refers to the general transformation of compost organic matter between the non-humic and humic-like fractions. The degree of evolution has been evaluated by means of a number of humification parameters and the OMEI that are different ratios of the carbon content of compost organic matter fractions. The OMEI, unlike the humification parameters, involves the pre-purification of the humic acid fraction through the removal of coating compounds associated with humic acids such as lipids, waxes, hemicellulose, proteins and cellulose. Results obtained for the humification parameters in our samples show a high degree of variability with composting time and similar values were obtained for the initial feedstock and final compost. This seems to suggest that these parameters are not always capable of describing the humification process. On the other hand, the OMEI increases with composting time with a final value exceeding 0.6, the threshold described by Adani *et al.*, (1997) for the attainment of compost stability.

The oxidative degradation of labile organic matter and the synthesis of humic-like compounds occur concurrently during composting, even though the former plays a major role during the active composting phase. For this reason the parameters that describe the changes in these phenomena with composting time are expected to be negatively correlated to some extent. Amongst the various indices generally used to describe the evolution of organic matter, only the OMEI shows a significant correlation ($p \leq 0.05$) with the respiration indices for the samples analyzed.

The seed germination tests were used to evaluate changes in compost phytotoxicity during the composting process. The germination indices (GI) obtained for SCOM1, SCOM2 and TCOM1 increased over the composting process by 60%, 67% and 62% respectively and clearly show a trend of decreasing phytotoxicity with composting time, with the most significant increase occurring after 60 days of composting. Phytotoxicity or poor plant response can result from several factors the most important of which are a high oxygen demand, the accumulation of toxic compounds such as alcohols, methane, low molecular weight organic acids, ammonia and toxic nitrogen compounds, the immobilization of nitrogen with high C/N ratios, and the presence of heavy metals and mineral salts. The results obtained for the GI show a negative, significant correlation with the respiration indices (SOUR and OD_{12}) as well as the organic carbon content of DOM and its hydrophilic fraction for SCOM2 and TCOM1. This shows that the decrease in phytotoxicity with composting time is greatly influenced by the phenomena that occur in the soluble fraction.

The phenomena that occur during the composting process, that describe the changes in stability and maturity as well as the evolution of organic matter, are closely related and amongst the indices used to evaluate these changes, the SOUR, HoDOM:HiDOM ratio, OMEI and GI are clearly correlated. Results have also shown that these indices are independent of the initial composition of the feedstock and also on the composting process used. Although the results show that phytotoxicity is dependant on the oxygen demand and concentration of organic compounds in DOM, further investigations are required to identify the crucial phenomema on which phytotoxicity depends, and to better understand the processes that reduce feedstock phytotoxicity with composting time.

References

Adani F., Genevini P.L., Gasperi F. and Zorzi G., (1997) Organic matter evolution index (OMEI) as a measure of composting efficiency. *Compost Science and Utilization* **5**(2):53-62.

Adani F., Gigliotti G., Valentini F. and Laraia R. (2003) Respiration index determination: a comparative study of different methods. *Compost Science and Utilization* **11**(2):146-153.

Brewer L.J. and Sullivan D.M., (2003) Maturity and stability evaluation of composted yard trimmings. *Compost Science and Utilization* **11**(2):96-112.

Chica A., Mohedo J.J., Matrín M.A. and Martín A., (2003) Determination of the stability of MSW compost using a respirometric technique. *Compost Science and Utilization* **11**(2):169-175.

Ciavatta C., Govi M., Vittori Antisari L. and Sequi P., (1990) Characterization of humified compounds by extraction and fractionation on solid polyvinylpyrrolidone. *Journal of Chromatography* **509:**141-146.

Cooperband L.R., Stone A.G., Fryda M.R. and Ravet J.L. (2003) Relating compost measures of stability and maturity to plant growth. *Compost Science and Utilization* **11**(2):113-124.

Epstein E. (1997) *The Science of Composting*, CRC Press LLC, Florida, U.S.A.

Gigliotti G., Kaiser K., Guggenberger G. and Haumaier L. (2002) Differences in the chemical composition of dissolved organic matter from waste material of different sources. *Biol Fertil Soils* **36:**321-329.

Lowe L.E. (1993) Total and labile polysaccharide analysis of soils, In: Carter M.R. (ed.) *Soil sampling and methods of analysis*. Canadian Society of Soil Science, Lewis Publishers, pp. 373-376.

Ministero delle Politiche Agricole e Forestali (2001) *Metodi di analisi delle acque per uso agricolo e zootecnico*. G. Mecella (ed.) Società Italiana della Scienza del Suolo, FrancoAngeli, Milan, Italy.

Sanchez-Monedero M.A., Roig A. and Bernal M.P., (2001) The water soluble organic fraction and its relationship to the degree of maturity of organic matter during composting. *Orbit Journal* **01:**

Zucconi F., Monaco A., Forte M. and De Bertoldi M. (1985) Phytotoxins during the stabilization of organic matter, In: Gasser J.K.R. (ed.) *Composting of Agricultural and Other Wastes.* Elsevier Applied Science Publishers, London, pp. 73-86.

Acknowledgements

This research was partially financed by the Italian Ministry for University and Research (COFIN 2003 fund).