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# The Use of a Respirometric Technique for Assessing the Evolution of the Stability of a Sewage Sludge Compost Developed under Full-Scale Conditions

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## ABSTRACT

Composting is one of the best ways to properly manage the high production of sewage sludge with the aim of obtaining sanitized products with a stable organic matter. The evolution of the stability of a compost consisting of sewage sludge, straw and sawdust, developed under full-scale conditions, was analyzed. The stability was assessed by a respirometric assay performed for 30 days, where the $O_2$ consumption and $CO_2$ production was continuously measured by an automatic respirometer. Important reductions were observed in the respirometric parameters, changes which mainly occurred in the samples taken during the first 40-50 days of composting. After this period, the few changes observed and the low levels of respiration suggested compost stability. The maximum rates and the cumulative values of $CO_2$ and $O_2$ after 8 days of incubation seemed to be the most useful respirometric parameters for compost monitoring.

**Keywords:** composting, mineralization, monitor, respirometer, stability

**Abbreviations: AT4**, respiration activity after 4 days; **DRI**, dynamic respiration index; **RQ**, respiratory quotient; **SOUR**, specific oxygen uptake rate; **v/v**, volume/volume

## INTRODUCTION

The stability and maturity of composts is one of the main requirements for their adequate use as soil amendment in agriculture or environmental restoration. Although normally related, maturity and stability respond to different concepts. Stability is related to the microbial activity of wastes (Bernal *et al*. 1998a), whereas maturity is associated with plant-growth potential or phytotoxicity (Iannotti *et al*. 1993). The use of unstable composts as soil amendments may immobilize soil mineral nitrogen, degrade indigenous organic matter, inhibit seed germination, reduce plant growth, and produce unpleasant odors (Iglesias-Jiménez and Pérez-García 1989; García *et al*. 1992; Bernal *et al*. 1998b; Veeken *et al*. 2000; Hoekstra *et al*. 2002). Several methods have been used to assess compost stability including C:N ratio, inorganic N, $CO_2$ and $O_2$ evolution, the nitrification index ($NH_4$-N/$NO_3$-N), water-soluble organic carbon, cation exchange capacity, UV-spectra and infrared spectroscopy (FTIR), thermal analysis, anaerobic and temperature test methods among others (Aparna *et al*. 2008; Carballo *et al*. 2008; Hutchinson and Griffin 2008; Kalamdhad *et al*. 2008; Sellami *et al*. 2008; Vergnoux *et al*. 2009; Wagland *et al*. 2009).

Although no single method can be universally applied due to the wide range of feedstocks and different composting processes (He *et al*. 1995; Hutchinson and Griffin 2008), the analyses involving organic matter decomposition seem to be the most reliable methods of determining compost stability (Busby *et al*. 2007), specifically using tests based on respirometric activity (Lasaridi *et al*. 1998; Rynk 2003; Adani *et al*. 2006; Barrena-Gómez *et al*. 2006). This activity can be assessed by different methods, with NaOH traps and automatic respirometers being frequently used. Some automatic respirometers offer the possibility of monitoring both $O_2$ consumption and $CO_2$ production, which allows for the determination of the respiratory quotient (RQ, moles $CO_2$ over moles $O_2$), also used for monitoring and control the composting process (Atkinson *et al*. 1997; Kalamdhad *et al*. 2008). Haug (1986), Palestski and Young (1995) and Adani *et al*. (2002) agree that, in terms of stability, methods based on monitoring of $O_2$ uptake are better than those that monitor $CO_2$ production because $O_2$ uptake is directly related to the microbial respiration and oxidation of organic matter.

Most published research on composting processes has been conducted on small research-scale operations (Said-Pullicino *et al*. 2007). Thus, the stability of a full-scale sewage sludge composting process was monitored using a 30 days respirometric assay. The different parameters derived from this assay were compared with the aim of selecting the most suitable to assess the evolution of the stability of the compost samples. Moreover, it is well known that compost production is a time and money consuming activity. Thus, this information wants to be used to ascertain the correct development of the process in order to decide when the material could be considered ready to use in terms of stability.

## MATERIALS AND METHODS

### Composting process

The composting process was developed in a municipal wastewater treatment plant in Alicante province (SE Spain). Compost consisted of sewage sludge mixed with sawdust and straw as bulking agents in a proportion of 4:3:1 (v/v). Straw favours aeration and sawdust absorbs moisture, improving at the same time the C/N ratio (values for the source materials in **Table 1**). The composting facility has two consecutive composting tunnels (tunnel T and tunnel M) of 67 m long, 3 m wide and 1.75 m high. The mean residence time of samples at each tunnel is approximately 49 days. The material is turned three times per week, allowing the movement of compost samples along the tunnels. In the final stage, compost is transferred outside and placed in large piles to await

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**Table 1** Contents of TC and TN, and their ratio, for the source materials used in the composting process.

| | TC (%) | TN (%) | TC/TN |
|---|---|---|---|
| Sewage sludge | 40.9 | 6.9 | 6.0 |
| Straw | 45.9 | 0.5 | 86.7 |
| Sawdust | 39.4 | 0.8 | 51.4 |

TC : Total carbon ; TN : Total nitrogen

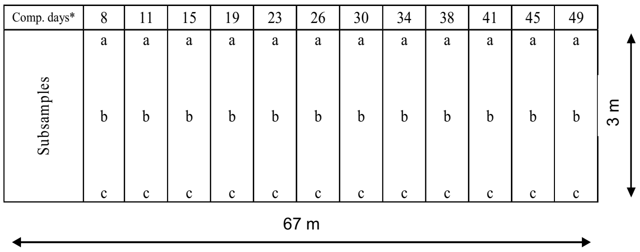


**Fig. 1 Details of T tunnel and sampling strategy.** * Comp days = Composting days.

packing and commercialization.

Our work was centred on samples corresponding to tunnel T since the most important changes are expected to happen during the first weeks of composting. Samples in this tunnel represented approximately 8, 11, 15, 19, 23, 26, 30, 34, 38, 41, 45 and 49 composting days. For each sample point (except for samples with 49 composting days), three subsamples representing the width of the composting tunnel were taken (details of tunnel characteristics and sampling strategy in **Fig. 1**), resulting a total of 34 samples analyzed. Each subsample was composed of a mixture of samples taken at different profundities (from the top to the bottom of the pile). In tunnel M, samples corresponded to approximately 53, 57, 60, 64, 68, 72, 75, 79, 83, 87, 90, 94 and 98 composting days. In the final stage three sample points representing 112, 158 and 278 composting days, were selected. Sample strategy was the same than the previously explained for tunnel T. However, in both tunnel M and final stage, where few changes and more homogeneity is expected for compost samples, selected subsamples from each sample point were analyzed, resulting in 21 samples in tunnel M and 4 in the final stage.

## Respirometric assay

The mineralization analysis was performed using an automatic respirometer (Micro-Oxymax, Columbus Inc, EEUU). One gram of compost was mixed with 12 g of silica sand and maintained at 60% water-holding capacity and 25°C for 30 days. This device analyses both $O_2$ uptake (with a paramagnetic sensor) and $CO_2$ release (with an infrared sensor) at time intervals (every 5 hours), and it is considered as a static method, although the air of the chambers where the samples are contained is replaced after each measurement. The cumulative values after 8 and 30 days of incubation and the maximum rates were calculated for each sample. Using the $CO_2$ and $O_2$ values after the 30 days of incubation, the RQ was also calculated.

## Statistical analyses

The results are presented as the means values (± standard error) of the subsamples analysed at each sample point in tunnel T. Obviously, no statistics are presented when one single subsample was analysed per sample point (sample with 49 composting days in tunnel T, and some samples in tunnel M and final stage). The software used was SPSS v.15.0 and Microsoft Excel 2003.

## RESULTS AND DISCUSSION

Changes in the $O_2$ and $CO_2$ maximum rates during the composting process are presented in **Fig. 2**. This figure reflects how the most important changes occurred during the first 40-50 days of composting. From this point to the final part of the process, few changes were observed.

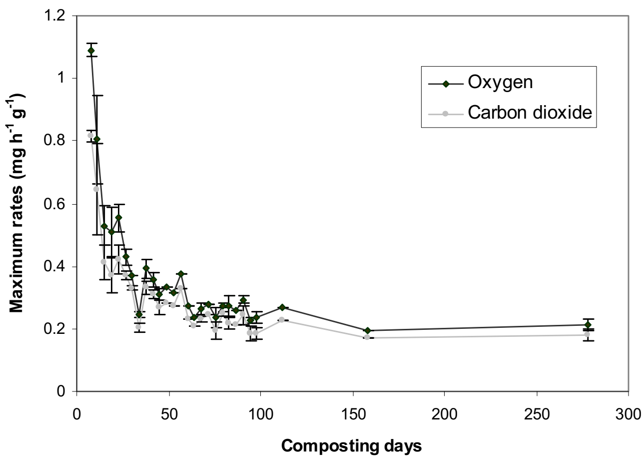


**Fig. 2 Changes in the $O_2$ and $CO_2$ maximum rates (means ± standard error) during the composting process.**

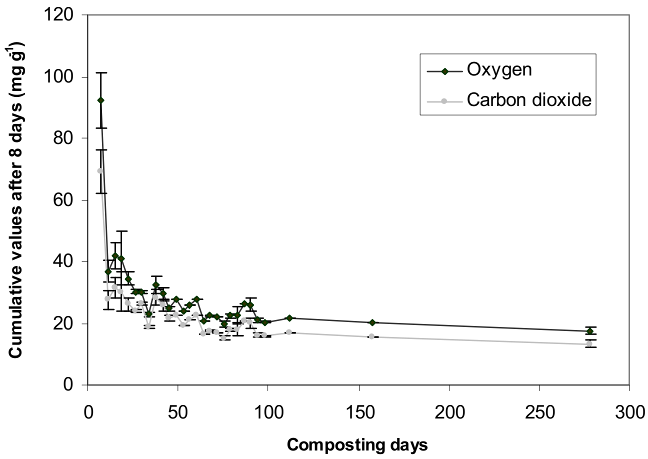


**Fig. 3 Evolution of the cumulatve $O_2$ and $CO_2$ values after 8 days of incubation (means ± standard error) during the composting process.**

**Fig. 3** shows the cumulative $CO_2$ and $O_2$ values after 8 days of incubation. The conclusions are similar to the exposed for the maximum rates. Both parameters can be useful tools to characterize the early decomposition dynamics of waste prior to their application and they have been proposed as stability parameters (Lasaridi and Stentiford 1998; Boulter-Bitzer *et al*. 2006). In fact, several rapid tests related to $O_2$ uptake have been proposed as stability indexes for compost: the German index for respiration activity based on the $O_2$ uptake over 96 h (AT4; Binner and Zach 1999), the DRI (Dynamic Respiration Index), which measures the average instantaneous oxygen consumption kinetics for 24 h after the maximum respirometric activity has been reached (Adani *et al*. 2001), and the SOUR (specific oxygen uptake rate) which uses the maximal oxygen consumption (Lasardi and Stentiford 1998).

The cumulative $CO_2$ and $O_2$ values after 30 days of incubation were also considered since $O_2$ and $CO_2$ accumulations after long periods have been proposed as well as stability parameters (Bernal *et al*. 1998a; Shepherd *et al*. 2005). The results are presented in **Fig. 4**. Again, an important reduction in the respiration levels was observed during the first days of composting, however, this parameter showed more heterogeneity for samples from 50 to 100 days of composting.

As can be observed in **Fig. 2, 3** and **4**, the $O_2$ and $CO_2$ values presented almost identical patterns; however, the levels of oxygen were always higher. The RQ may vary depending on the composition of available substrates, the current physiology of the microbial communities and microbial adjustment to the nutritional conditions (Dilly 2001). Apart from that, $CO_2$ emission can be underestimated when using

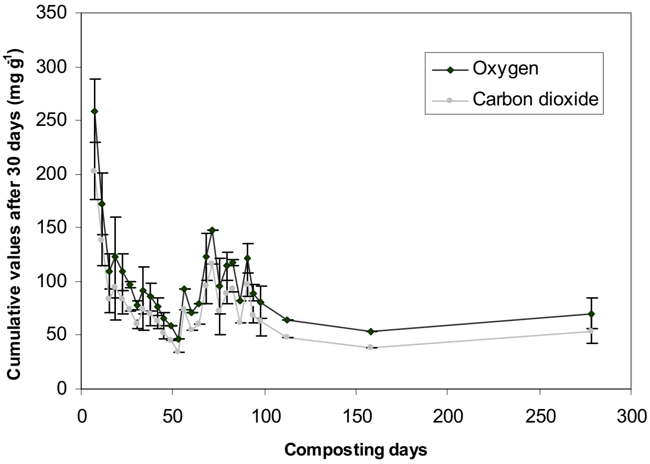


**Fig. 4 Evolution of the cumulative $O_2$ and $CO_2$ values after 30 days of incubation (means ± standard error) during the composting process.**

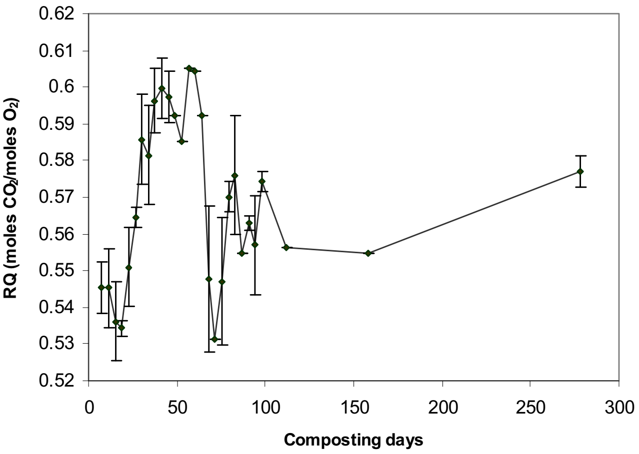


**Fig. 5 Evolution of the respiratory quotient (RQ) during the composting process.**

the respirometer method because some of the $CO_2$ may be retained in the solution phase (Sparling and West 1990), and hence affects the RQ. However, the air replacement after each measurement and the small quantity of water in the waste-silica sand mixture seemed to minimize the possible effect of $CO_2$ dissolution. The RQ (**Fig. 5**) did not exhibit a constant trend throughout the composting process but it seemed to indicate changes in the microbial community, fact that need to be confirmed with further analyses. Similar results were found in the study of Kalamdhad *et al*. (2008).

## CONCLUSIONS

Important reductions were observed in the respirometric parameters, changes which mainly occurred in the samples taken during the first 40-50 days of composting. After this period, the few changes observed and the low levels of respiration suggested compost stability. The maximum rates and the cumulative values of $CO_2$ and $O_2$ after 8 days of incubation, seemed to be the most useful respirometric parameters for compost monitoring, considering the rapidity of the analysis and the constant trend observed along the process. These analyses must be completed with a field test involving the main destination of the compost, the agricultural soils.

## ACKNOWLEDGEMENTS

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