Assessing the stability and maturity of compost at large-scale plants

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ABSTRACT

Four different tests to assess compost stability were compared during green waste composting in windrows at a large-scale composting plant. The tests used were: germination index (based on seed germination); SOUR (specific oxygen uptake rate, respirometric method based on O_2 consumption by the microorganisms); self-heating test (reflecting the energy output from the aerobic process); and Solvita® (a commercial maturity test based on CO_2 and NH_3 production). These methods have been identified previously as suitable parameters to establish the end-point of the composting process and results were compared to the typical process parameters which include temperature, pH, electrical conductivity, moisture content and volatile solids. SOUR was found to give a useful indication of the degree of stabilisation of organic matter during the first stages of the composting process. Solvita®, was found to reflect more the degree of maturity of the compost, and that was more useful at the later stages of the composting process. This study showed that SOUR and Solvita® provided fast, simple and relatively unsophisticated methods to monitor compost stability and maturity at large-scale composting plants processing green wastes.

Keywords: green wastes, compost stability, germination index, self-heating, Solivita®, SOUR.

Evaluación de la estabilidad y madurez de la composta en plantas de escala real

RESUMEN

Se compararon cuatro pruebas diferentes para evaluar la estabilidad de la composta durante el proceso de composteo de residuos de jardinería por el método de volteo a cielo abierto en plantas a escala real. Las pruebas usadas fueron: índice de germinación (basado en la germinación de semillas); SOUR (siglas en ingles de la tasa de consumo específico de oxígeno, método respirométrico basado en el consumo de O_2 por los microorganismos); autocalentamiento (prueba que refleja la energía liberada durante el proceso aerobio); y Solvita® (una prueba comercial de la madurez basada en la producción de CO_2 y NH_3). Estos métodos han sido identificados en trabajos previos como parámetros convenientes para establecer el punto en el que finaliza el proceso de composteo. Los resultados se compararon con los parámetros del proceso típico que incluyen: temperatura, pH, conductividad eléctrica, humedad y sólidos volátiles. Se encontró que el SOUR proporciona información útil del grado de estabilización de la materia orgánica durante las primeras etapas del proceso. Se concluyó que la prueba con Solvita®, fue más adecuada para reflejar el grado de madurez de la composta y más útil en las últimas fases del proceso de composteo. Este estudio demostró que las pruebas SOUR y Solvita® son métodos sencillos y rápidos para supervisar estabilidad y madurez del material durante el proceso de composteo de residuos de jardinería por el método de volteo a cielo abierto en plantas de tamaño real.

Palabras clave: residuos de jardinería, estabilidad de la composta, índice de germinación, Solivita®, SOUR.

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INTRODUCTION

The establishment of a generally accepted stability index suitable to be used as a routine test at a large-scale composting facility is still a major area of research in waste management. According to Haug (1993), compost is sufficiently stabilised when the rate of oxygen consumption is reduced to the point in which anaerobic or malodorous conditions are not created such that they interfere with the storage, marketing and use of the end product. In addition, stabilised compost should not have problems with vermin attraction, pathogen re-growth or other problems resulting from its incomplete decomposition. Confusion often occurs over the difference between stabilised and mature compost. Compost maturity generally relates to the agricultural 'value' of the compost in relation to its effect on the soil and plants' response to its application. The degree of compost maturity required for an agricultural application depends on the type of application, but regardless of this, there is a baseline requirement for stable compost.

There are no universally accepted standards for the evaluation of compost stability. Several countries in Europe have produced and use their own set of standards and others are in the process in doing so (European Commission, 2001). As composting is an aerobic microbial process, methods based on microbial activity are considered by researchers and regulators to be the most logical ones for the assessment of compost stability. These are either directly related, such as the measurement of respiration using O_2 uptake or CO_2 production, or indirect reflections, such as self-heating and the evolution of other parameters such as volatile solids, C/N ratio, humification indices, nitrification, etc, (Iglesias-Jiménez and Pérez-García, 1992; Bernal et al, 1998). Most of these suggested methods are either time consuming or require very sophisticated equipment. This represents a problem from a practical point of view as an on-site monitoring method. A routine method to test compost stability and maturity at a full scale composting plant should have certain characteristics which make it suitable for the conditions. The method should be simple, unsophisticated and easy to use by the staff working on site. The test should also give a clear response to allow users distinguishing between the different composting stages and to indicate clearly the end-point of the composting process. From the methods described in the literature, four tests: germination index, SOUR, self-heating test and Solvita® were selected for evaluation as they seemed to be suitable for use as a routine on-site method. The germination index is a maturity test based on seed germination and initial plant growth using a liquid extract from the compost (Zucconi, *et al.* 1981). It reflects the phytotoxicity of the compost extracts at different stages of composting. The compost is considered mature when the germination index is higher than 60 %, compared to the control with distilled water (Zucconi and de Bertoldi, 1987). This method has been widely used and the seed germination requires from 24 to 48 hours. SOUR (specific oxygen uptake rate) is a respirometric method based on O_2 consumption by microorganisms degrading a liquid suspension of the organic matter (Lasaridi and Stentiford, 1998). A low specific oxygen uptake rate indicates that the majority of the readily biodegradable material has been degraded, giving rise to a more stable end product. This method requires between 12 and 24 hours, depending on the degree of stabilization of the material being tested. The self-heating test is an indirect measure of microbial respiration through temperature rise of a sample held in Dewar flasks, which is adjusted to a given set of conditions (FCQAO, 1994). The rate of microbial respiration affects the heat output which is reflected in the temperature rise. The higher temperature reaches, the less stable the material is.

Despite several problems with the method, its low cost and simplicity have promoted its wide scale application as stability test in several countries (Lasaridi, 1998). The Solvita® test is a relatively new commercial maturity index based on measuring carbon dioxide respiration and ammonia content simultaneously in the same test. It is very simple to use and gives a response only after 4 hours. The aim of this work was to compare these four test-methods in a full- scale operation.

MATERIALS AND METHODS

The composting took place at a large-scale composting plant in the North of England. The feedstock of shredded green wastes was composted in trapezoidal cross section windrows 25 m x 3 m x 2 m, (length x width x height) over a 18 week period. The windrows were turned using a loading shovel twice a week for the first 10 weeks and then, the material was allowed to mature for a period of 8 weeks with no turning. The temperature was monitored daily using thermocouples placed near the centre of the pile at six different points along its length. A representative sample of approximately 6 kg was taken once a week after turning. The sample was a composite made up from 10 grab subsamples taken along the length of the windrow. The samples were screened through a 10 mm sieve and kept refrigerated for physico-chemical analysis.

Monitoring of the composting process. Electrical conductivity and pH were measured using a suspension of 10 g in 100 ml of distilled water. Moisture content was determined by drying at 105°C for 24 hours and expressed as a percentage of total weight. Volatile solids were determined on the dried sample taken from the moisture content test by measuring loss on ignition at 550°C for 3 hours. The weight loss represented volatile solids that were expressed as a percentage of dry solids.

Stability and maturity methods. Germination index was determined using an adaptation of the method of Zucconi, *et al.* (1981). 10 g of screened sample were shaken with 100 ml of distilled water for 1 hour. The suspension was centrifuged for 15 minutes at 3000 rpm and the supernatant was filtered through a Whatman No 6 filter paper. 10 cress seeds (*Lepidium sativum*) were placed on filter paper Whatman No 1 in a Petri dish of 10 cm diameter. Two ml of the extract were added to the Petri dish. Two ml of distilled water were used for control. The test was run in triplicate. Petri dishes were left on laboratory bench and after 48 hours, the total length of each cress root was measured. If the seeds did not germinate, their root length was considered to be 0 mm. The germination index is given as a percentage based on total length of roots on the test plates x 100 divided by total length of roots on the control plates.

The self-heating test was performed according to the method described in FCQAO (1994). A screened sample with its moisture content adjusted to around 55 % was placed in insulated Dewar vessels and a thermocouple was placed into the centre of the material at the two-thirds point from the top. At the end of the test, the maximum temperature reached (Tmax) was used to determine the rotting degree which ranges from I (Tmax between 60 and 70°C) for active materials to V (Tmax between 20 to 30°C) for mature compost.

The Solvita test was performed according to the instruction manual from the manufacturer (Solvita® 1999). A screened sample adjusted to moisture content around 55 % was placed in the kit jar to the fill line. Tapping sharply the bottom of the jar on a counter ensured the right density. Paddles with the reactive gel were inserted in the sample jar and its lid was screwed tight. The jars were kept at room temperature (20 – 25°C) away from sunlight for 4 hours. After that, the colours of the gel paddles were noted and compared to the manufacturer's standards. A Solvita® maturity index was then obtained ranging from 1, for unstable material, to 8 for mature compost.

The specific oxygen uptake rate (SOUR) was performed according to the method described by Lasaridi and Stentiford (1998). The SOUR was measured on a liquid suspension of compost (5 g of compost in 500 ml of distilled water added with $CaCl_2$, $MgSO_4$, $FeCl_3$ and phosphate buffer at pH 7.2) incubated in a water bath held at 30°C for 24 hours. During this time, the suspension was alternately aerated for 15 min and then allowed to stand with slow stirring only during which time the O_2 concentration was measured continuously. The respiration rate typically reached a peak after around 12 hours and this value was quoted as the SOUR in mg O_2/ gVS/hour.

RESULTS AND DISCUSSION

Monitoring of the composting process. Fig. 1 shows the changes in the main parameters used to monitor the green waste composting process. These parameters showed that green wastes had undergone a typical composting process as would be expected with this kind of material (Frederickson, *et al.* 1997). The temperature reached a maximum of 73°C after 2 weeks of operation and remained above 50 °C for 7 weeks. Afterwards, temperature diminished to levels between 30 and 40 °C during the maturation phase. The temperature evolution was the main parameter used by site staff to follow the composting process because this parameter reflects microbial activity and also because it is easy to perform. When the temperature diminished below 40°C, after 10 weeks of composting, the active phase was considered to be finished and the windrow turning was stopped.

The moisture content remained around 60 % during the whole composting process, which was around the optimum range for microbial activity with this material.
The other monitoring parameters were also as expected in Windrow composting systems.

Volatile solids were reduced by 28 % of the initial amount during the composting process. The majority of volatile solids reduction occurred during the first 6 to 8 weeks, when the higher temperatures were recorded, and little further decrease was detected during the maturation process. The values of pH followed the normal pattern expected during composting, rising progressively over the first 6 to 8 weeks, and then remaining fairly stable with values between 8 and 8.5. As a general pattern, all the physico-chemical monitoring parameters indicated that the active phase of composting process was finished after 10 weeks, and then the pile was allowed to mature for an additional period of 8 weeks.

Stability and maturity tests. Table 1 shows changes in the four parameters used to assess compost stability.

The SOUR reduced rapidly from an initial value of 5.89 to a value of 0.51 mgO_2/gVS/ hour during the first three weeks. This reduction was followed by a slow gradual further reduction which led to a minimum value of 0.39 mgO_2/gVS/hour for the material at the end of the composting process. According to Lasaridi and Stentiford (1998), this SOUR level indicated that the material was 'stable', within 4 weeks, which meant that the material was unlikely to pose a problem in relation to odour if it was stored under reasonable conditions, even without turning.

The temperature recorded at week 4 indicated that significant microbial activity was still taking place nevertheless these high temperatures can be maintained with relatively low activity because the insulating properties of the material are so good. It is essential that stability test results allow users to differentiate between the effects of microbial activity and the physical properties of the material.

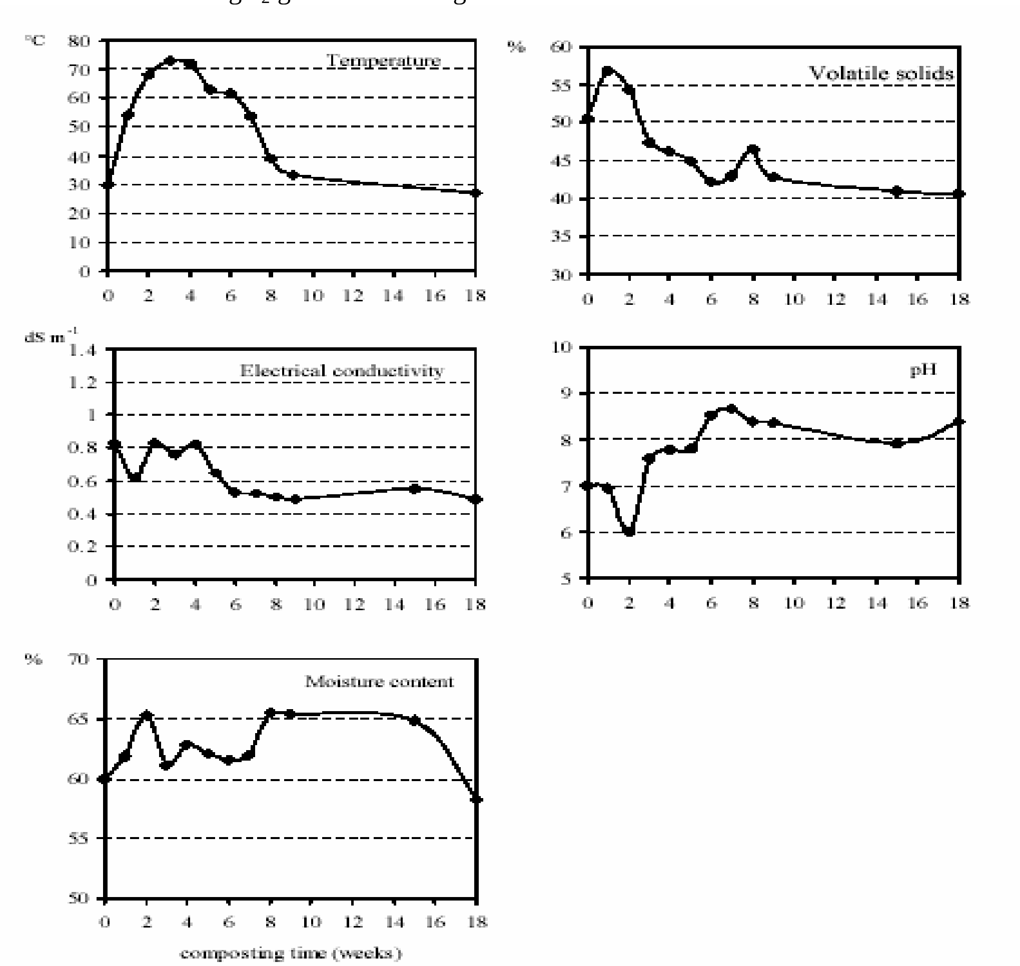

Figure 1. Changes in the main physico-chemical parameters monitored during the composting process (in weeks).

The Solvita® test showed that the material was in an 'active' phase for one week, according to the manual, and then during weeks 2 to 3 the compost was in a 'moderately active' stage of decomposition. From week 4 and for the rest of the period, the compost had a Solvita® maturity index of 5, which indicated that compost was ready for curing. After 15 weeks, the Solvita® maturity index was 6, which corresponds to a still active compost but with significantly reduced management requirements. This method seems to have given an underestimate of the compost maturity compared to the other tests used.

The self-heating test gave contradictory results to the results of the Solvita® test. According to these results, the material was at 'Rotting Degree' 4, corresponding to compost ready for curing, after only one week of composting and then at 'Rotting Degree 5' after 10 days of composting, that correspond to a cured compost. However, it is not reasonable to obtain a stabilized product after only 10 days of windrowing, and other parameters such as SOUR indicated that the material was still quite active. This inconsistency probably resulted from an incorrect use of the method, as previous work has shown that staffs need to develop expertise with this method to ensure its reliable performance.

The results from a cress-seed germination bioassay showed that the material did not have strong phytotoxic effects on the seeds as the material always showed relatively high germination index, regardless of the degree of stability. After 3 weeks the germination index was around 100 % indicating stable compost. The fluctuations below 100 % on weeks 6 and 15 are in line with the findings of Zucconi and de Bertoldi (1987). The values for the germination index after the third week of the process suggested that the material would not have any phytotoxic effects, even if the decomposition of the material was still taking place. The high percentage of seed germination, even at early stages of the composting process, might represent a limitation of this test as stability indication, in the case of greenwastes.

SOUR and self-heating tests indicated that the end-point was reached only after 4 or 5 weeks but problems with the selfheating test meant that the use of its results in this case is questionable.

Maturity tests, germination index and Solvita®, indicated that the material would not show any plant phytotoxicity after 4 or 6 weeks of composting.

Table 1: Results for the stability tests carried out on composted green waste of different ages.

Weeks of composting	Self heating (T_{max} ºC)	Solvita Maturation index	SOUR (mgO_2 gVS^{-1} $hour^{-1}$)	Germination index (%)
0	54.5	3	5.89	71.7
1	33.1	3	3.10	64.6
2	25.6	4	0.80	71.8
3	16.3	4	0.88	98.7
4	15.9	5	0.51	102.7
5	14.0	5	0.42	105.7
6	13.6	5	0.45	88.0
10	13.0	5	0.39	90.2
15	-	5	0.42	123.3
18	-	6	0.39	98.5

CONCLUSIONS AND RECOMMENDATIONS

SOUR appeared to be good stability indicator. This was expected given that it is a test based on respiration rates, which reflect well the changes in activity at the early stages of composting. Solvita® results proved to be good indicators for compost maturity and were more useful at the later stages of the composting process. SOUR and Solvita® represent fast, simple and unsophisticated methods to monitor compost stability and maturity at large-scale composting plants processing green wastes.

REFERENCES

Bernal M.P., Paredes, C., Sánchez-Monedero, M.A. and Cegarra, J. (1998). Maturity and stability parameters of composts prepared with a wide range of organic wastes. "Bioresource Technology", (63), 91-99.

European Commission. (2001). Biological treatment of Biowaste. Working document, 2nd draft.

FCQAO (Federal Compost Quality Assurance Organization). (1994). Methods Book for the Analysis of Compost. Kompost-Information Nr. 230. Budesgutegemeinschaft Kompost e.V. English translation by W. Bidlingmaier, Univ. of Essen, Germany.

Frederickson, J., Butt, K.R., Morris, R.M. and Daniel, C. (1997). Combining vermiculite with traditional green waste composting systems. "Soil Biology and Biochemistry", (29), 725-730.

Haug, R.T. (1993). The Practical Handbook of Compost Engineering. Lewis Publishers, USA.
Iglesias-Jiménez, E. and Pérez-García, V. (1992). Determination of maturity indices for city refuse composts. "Agriculture, Ecosystems and Environment", (38), 331-343.

Lasaridi, K.E. (1998). Compost stability: a comparative evaluation of respirometric techniques. PhD Thesis, University of Leeds. UK.

Lasaridi, K.E. and Stentiford, E.I. (1998). A simple respirometric technique for assessing compost stability. "Water Research", 32(12), 3717-3723.

SOLVITA® (1999). Guide to Solvita® testing for compost maturity index. Woods End Research Laboratory, Inc. USA

Zucconi, F. and de Bertoldi, M. (1987). Compost specification for the production and characterisation of compost from municipal solid waste. In: Compost, production, Quality and Use. Eds: M. de Bertoldi, M.P. Ferranti, P. L'Hermite, F. Zucconi. Elsevier Applied Science. pp, 30-50

Zucconi, F., Pera, A., Forte, M. and de Bertoldi, M. (1981). Evaluating toxicity of inmature compost."BioCycle",22,54-57