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Respiration indices and stability measurements of compost through electrolytic respirometry

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ABSTRACT

An experimental technique for compost stability measurements based on Sapromat electrolytic respirometry was optimised and subsequently applied to a sludge composting process. Anaerobically digested sewage sludge mixed with reed was composted during 90 days in a pilot-scale rotary drum with forced aeration. Periodic solid samples were taken, and a previously optimised respirometric procedure was applied in order to measure the oxygen consumption. The respirometric experiments were made directly with a few grams of solid samples, optimum moisture and 37 °C over a period of 96 h. The results obtained showed how the respiration activity of the sludge decreased during the composting experiment under the specific operating conditions. The specific oxygen uptake rate (SOUR) instant values from the oxygen consumption curves were obtained, and two commonly used respirometric indexes (RI_{24} and AT_4) were calculated for all samples. Both RI_{24} (a mean of the SOUR values during the 24 h maximum activity period) and AT_4 (total oxygen consumption after 4 days) were the recommended parameters for the estimation of compost stability by the European Union in the second draft of the Working Document on the Biological Treatment of Biowaste in 2001. Both indexes exponentially decreased with the composting time, and a good linear correlation between them was observed. Final values of RI_{24} and AT_4 after 90 days were 600 mg O_2 $kgVS^{-1}$ h^{-1} and 26 mg O_2 gTS^{-1}, respectively. We also considered if this technique could be classified as a Dynamic or Static method, the two primary respirometric techniques for measuring compost stability. Supposing that the proposed procedure is considered a dynamic method (no limitations on the amount of oxygen supply), the final RI_{24} obtained was compared with the dynamic respiration index (DRI) proposed by the EU (1000 mg O_2 $kgVS^{-1}$ h^{-1}). Our result indicated that stable compost was obtained after 90 d. However, if a static limit was considered (AT_4 lower than 10 mg O_2 gTS^{-1} as proposed by the EU), our result would indicate that more residence composting time would be needed. Taking into account these results, the advantages and disadvantages and the validity of the proposed method are discussed.

1. Introduction

Composting is a natural process by which a biowaste is oxidised by microorganisms using atmospheric oxygen under controlled conditions. The final compost is a valuable product for agriculture and should be a stabilised material from an environmental point of view. Maturity and stability are two important compost characteristics. While maturity relates primarily to the agronomical characteristics, stability can be defined as the extent to which readily biodegradable material has decomposed (Barrena et al., 2006). An unstable biowaste contains high amounts of biodegradable organic material that cause pollution in the environment. Good compost should be free of such material and considered stable.

Different methods have been proposed to measure compost stability, and many scientific studies are available (Cossu and Raga, 2008; Barrena et al., 2009; Wagland et al., 2009). Respirometric techniques are considered one of the most adequate methods for measuring stability. These techniques are based on either oxygen consumption or CO_2 production measurements by an unstable biowaste; however, O_2 consumption methods are more generally recommended in the literature. The Respiration Index of a biowaste (RI) is defined as the rate of oxygen uptake and can be measured by different kinds of respirometric techniques. These techniques usually include oxygen uptake by carbon and also by nitrogen degradation.

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There are several methods proposed that have been compared and widely described by Lasaridi and Stentiford (1998), Adani et al. (2003) and Barrena et al. (2006), among others.

Electrolytic respirometry is a technique based on the manometric Warburg respirometer (Ros, 1993). This technique has been usually named as the Sapromat® system and it has been widely used to measure oxygen consumption by organic substances with different objectives: wastewater biodegradability, toxicity and inhibition tests, modelling and kinetics of biodegradation, anaerobic treatability, respiration of polluted soils, compost respiration. It has been previously used by the authors of this work for biological wastewater treatment studies (Cañizares et al., 2000; De Lucas et al., 2005; De Lucas et al., 2007). It was supposed that the application of the electrolytic system, with a solid-phase respirometry, it would be an interesting tool to monitor the respiration evolution of a sludge composting process.

Thus, the aim of this work is to study the application of electrolytic respirometry for the monitoring of a sludge composting process by measuring respiration indexes with respect to composting time, including stability measurements of the final compost obtained. First, the operating conditions were optimised, and then, the sludge-reed composting process was monitored. Finally, this technique was classified into one of the different groups of respirometric methods, and thus, the corresponding proposed RI threshold values were used to evaluate if the produced compost was stable. However, it is not the objective of this work to prove if this technique is better than the others. It would need a large experimental work. Electrolytic Respirometry using solid-state samples can offer advantages and disadvantages which will be explained at the Discussion section.

2. Materials and methods

2.1. Respirometer

A Sapromat electrolytic respirometer (Bioscience BI-1000, Bethlehem, PA, USA), previously described by Cañizares et al. (2000), was used. The respirometer is a closed system that contains several test vessels with electrolytic cells (Fig. 1).

The cells act as manometers and oxygen generation systems. The reaction temperature can be controlled by a water bath. The CO_2 produced by respiration is absorbed on traps containing a concentrated KOH solution. The electrolytic release of oxygen from a sulphuric acid solution begins when the manometer detects a pressure drop. When the initial pressure is re-established, the electrolysis is stopped. The amount of electricity consumed for electrolysis is proportional to the amount of oxygen consumed during microbial degradation. By coupling the measuring unit with a computer, a continuous recording of the oxygen consumption is obtained.

2.2. Materials and experimental procedure

A composting process was developed in a pilot-scale closed rotary drum with forced aeration (Fig. 2). The reactor contained biowaste and worked as a fixed bed that was eventually turned using the rotary system. A humidified and heated atmospheric air inlet was placed at the bottom. Leachates were re-introduced in the reactor, which helped to maintain the moisture.

The biowaste was a mixture of anaerobically digested sewage sludge and reed in a ratio of 2:1 (wet weight) and 2:5 (dry weight), and the characteristics of the mixture are indicated in Table 1. The sewage sludge was taken from a conventional domestic wastewater treatment plant. Reed (*Phragmites Australis*) harvested from

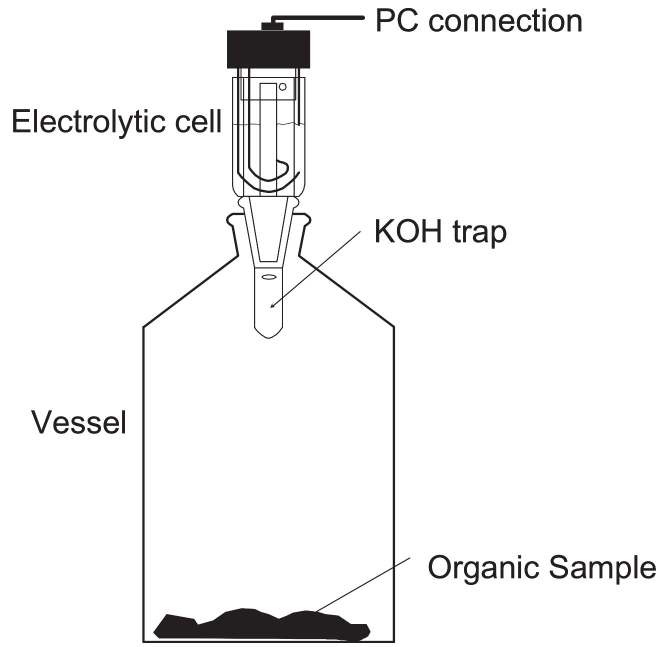

Fig. 1. Reaction vessel of an electrolytic respirometer.

a wetland in central Spain was milled and used as a co-substrate and amendment.

The sludge/reed mixture (90 kg, wet weight) was composted using the following conditions: excess oxygen (always more than 18% in exhaust air) and an air flow of 0.5–1 l min^{-1} kg^{-1} SV_o, with moisture between 40 and 60%. Total residence time (fermentation and maturation periods) was 90 days. Representative samples of 1 kg were taken (by triplicate) at days 1, 13, 33, 53 and 90.

A small portion of each sample (sub-sample) was introduced into a vessel of the respirometer. The vessel with the electrolytic cell was closed, and the oxygen generation system was connected. Then, the respirometer recorded the oxygen consumption of the solid sample. The following conditions were used in the respirometric tests: 30 g of sub-sample, 37 °C, moisture between 40 and 60% (that is, the same moisture maintained in the composting experiment), particles size less than 10 mm and residence time of 96 h (4 days).

Also, the composting trial was monitored. Another portion of each solid sample was mixed and a 250 g aliquot was used for analysis, while the rest of the sample was discarded and returned to the reactor. The aliquot was homogenised before analyses were performed. The parameters measured were the following: total C (%), total N (%), Volatile Solids (VS, %), NH_4^+/NO_3^- ratio, and the percentage of humic acid-like carbon (P_{HA}=(C_{HA}/C_{EX})×100) and the

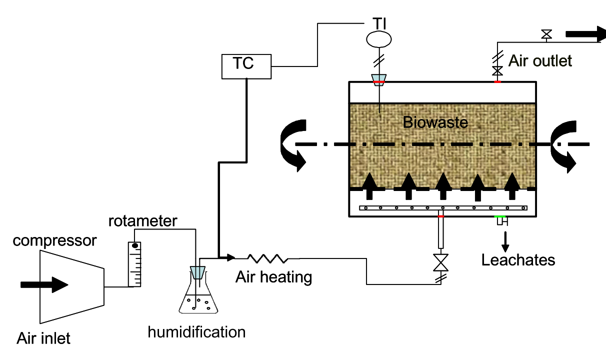

Fig. 2. Scheme of the pilot-scale composting experimental system.