Dehydrogenase activity as a method for monitoring the composting process

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Abstract

Dehydrogenase enzymatic activity was determined to monitor the biological activity in a composting process of organic fraction of municipal solid waste. Dehydrogenase activity is proposed as a method to describe the biological activity of the thermophilic and mesophilic stages of composting. The maximum dehydrogenase activity was detected at the end of the thermophilic stage of composting, with values within 0.5-0.7 $mg \cdot g$ dry $matter^{-1} \cdot h^{-1}$. Also, dehydrogenase activity can be correlated to static respiration index during the maturation mesophilic stage.

Keywords: Composting, Dehydrogenase activity, Organic fraction of municipal solid waste, Respiration index, Waste treatment.

Introduction

Composting is a biotechnological process in which organic solid matter is biodegraded under aerobic conditions (Haug, 1993). As interest in composting is growing, the need of reliable methods for determination of the biological activity of the process increases.

Different methods have been used for monitoring the biological activity of the composting process. At present, the most popular methods are based on the respiration of a solid compost sample under dynamic and static conditions (Scaglia *et al*., 2000; Adani *et al*., 2003). However, these methods only provide quantitative results when are carried out at identical conditions of the process, which is not always feasible (Mari *et al*., 2003).

Another group of methods is based on more specific biochemical properties such as RNA content (Liwarska-Bizukojc and Ledakowicz, 2001), ATP content (Horiuchi *et al*., 2003) or several enzymatic activities (Wong and Fang, 2000; Tiquia *et al*., 2002a; Mondini *et al*., 2004). Among these, dehydrogenase activity (DA) is related to a group of enzymes which participate in the metabolic reactions producing energy in the form of ATP through the oxidation of organic matter, which is especially interesting in the composting process. DA has been studied in few works to monitor the biological activity of the composting process (Wong and Fang, 2000; Tiquia *et al*., 2002b) and has been correlated with some operational and biochemical parameters such as temperature, nitrogen content or other enzymatic activities (Benitez *et al*., 2005). Recent works on composting (Tiquia, 2005) have successfully correlated DA with respiration activity.

The aim of the present study is the determination of DA throughout a whole composting process (including active thermophilic stage and maturation mesophilic stage) and to correlate it with the static respiration index (SRI), a typical monitoring parameter of biological activity of composting.

Materials and methods

Composted wastes

Source-selected organic fraction of municipal solid wastes (OFMSW) was selected as a substrate for composting experiments. OFMSW was obtained from a local composting plant and mixed with pruning wastes used as bulking agent in a volumetric ratio 3:1 (pruning wastes:OFMSW). Compost was obtained from the same composting plant at the beginning of maturation stage. In the composting plant studied, the beginning of the maturation stage starts when the material is extracted from a tunnel composting reactor in which the OFMSW is processed during 15 days of intensive composting. The main characteristics of OFMSW and compost are presented in Table 1.

Composting reactor

A 100 L dynamic composter was used in composting (OFMSW) and maturation experiments (compost obtained at the beginning of maturation stage). Briefly, the reactor permits the collection of leachates, the monitoring of temperature (Pt100 sensor, Desin mod. SR-NOH), the injection of air and the on-line analysis of oxygen content (Sensotran mod. Sensox) in exhaust gases. All sensors were connected to a data acquisition system. Material in the composter was turned daily.

Dehydrogenase activity (DA)

DA was determined according to standard procedures (Method 05.04-B) provided by the U.S. Department of Agriculture and U.S. Composting Council (2001).

Values of DA are expressed as mg of triphenyl formazan (TPF) released·g dry matter^{-1}·h^{-1} and are presented as an average of three replicates.

Static respiration index (SRI)

SRI was determined using a static respirometer based on the model previously described by Ianotti *et al*. (1993) and following the modifications and recommendations given by the U.S. Department of Agriculture and U.S. Composting Council (2001). Values of SRI are expressed as mg of oxygen consumed·g organic matter^{-1}·h^{-1} and are presented as an average of three replicates.

Analytical methods

Moisture, organic matter, N-Kjeldhal, electrical conductivity and pH were determined according to the standard procedures (U.S. Department of Agriculture and U.S. Composting Council, 2001). The composting material was manually homogenized prior to sampling. The volume of sample was 1 L to ensure a representative sample.

Results and discussion

Figure 1 shows the temperature profile of the OFMSW composting experiment. Temperature presented a typical pattern of a composting process (Haug, 1993), with a sharp peak of temperature at day 10 (70ºC) and a gradual decrease to mesophilic temperature from day 20. Thermophilic range of temperature (>45ºC) was maintained for more than 10 days, which ensures a complete sanitation of the material. Aerobic conditions were expected since the oxygen in the compost material was observed to be over 10% during the whole process. Moisture content, on the other hand, was maintained within the optimum range (50-60%) by regular water additions (data not shown).

DA profile is presented in Figure 1. Temperature and DA profiles were very similar during the thermophilic stage, both showing a rapid increase in the first days of composting. However, maximum values of DA (0.54 mg TPF·g dry matter^{-1}·h^{-1}) were observed at the end of thermophilic stage or at the beginning of mesophilic stage (days from 20 to 30). It is probable that at the end of the active composting stage maximum values of DA corresponded to a high biological activity, which gradually decreased in the maturation stage. Mesophilic conditions are typically considered in composting processes as equivalent to maturation stage (Haug, 1993). However, it is worthwhile to mention that if biological activity is considered, decomposition stage is extended during a long mesophilic period (60 days, Figure 1). Other authors have reported similar results in DA profiles, however, the initial peak is not always detected and the maximum DA values are usually lower (Wong and Fang, 2000; Tiquia *et al*., 2002b), which can be due to a more efficient oxygen control in the present reactor. Nevertheless, it is clear that DA is a useful parameter to follow the evolution of the biological activity of the composting process, since it correlates well with the temperature profile in the reactor.

Figure 1 also shows the evolution of the SRI during the composting of OFMSW. Although a similar trend to DA profile can be observed, the thermophilic stage is not completely characterized by the SRI. A possible explanation for this fact is that SRI is usually determined as a stability parameter and the assay conditions (mesophilic temperatures) were far from those found in the thermophilic stage of composting (Mari *et al*., 2003). On the other hand, the re-increase of SRI observed within the period 30-40 days can be attributed to a change of microbial communities or substrate redistribution.

Nevertheless, when mesophilic conditions were reached (from day 40) DA and SRI showed similar profiles.

To confirm this, SRI and DA were analysed in a maturation stage of a compost sample (Figure 2) under mesophilic conditions. Under these conditions, DA and SRI exhibited identical patterns. DA showed a significant positive correlation with SRI, with a correlation coefficient of 3.83 (significant at 0.05 and 0.01 probability levels). Other works have found positive correlations between DA and other operational composting parameters such as temperature, pH or some microbial communities (Benitez *et al*., 1999; Tiquia *et al*., 2002b). However, the positive correlation between DA and SRI found in this work enables the utilization of DA both as stability parameter of a compost sample and a microbiological activity indicator of the composting process, as it has been previously observed (Tiquia, 2005).

In summary, it can be concluded that DA is a useful method to describe the biological activity of the whole composting process and can be correlated with SRI (used as stability parameter) during the composting maturation stage.

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Tables

Table 1: Main characteristics of organic fraction of municipal solid waste and compost used in composting experiments.

Parameter	OFMSW	Compost
Moisture (%)	58.0	38.3
Organic matter (%, dry basis)	62.9	53.5
pH	6.9	8.2
Electrical conductivity (mS/cm)	3.0	5.2
N-Kjeldhal (% dry basis)	2.0	2.8
C/N ratio	17	11

Captions to Figures

Figure 1: Evolution of parameters in the composting of organic fraction of municipal solid waste. Temperature (-), Dehydrogenase activity (●) Static respiration index (▲). Vertical bars represent standard deviation (n=3).

Figure 2: Evolution of parameters in the maturation stage of composting of organic fraction of municipal solid waste. Dehydrogenase activity (●) Static respiration index (▲). Vertical bars represent standard deviation (n=3).

Figure 1: Barrena *et al*.

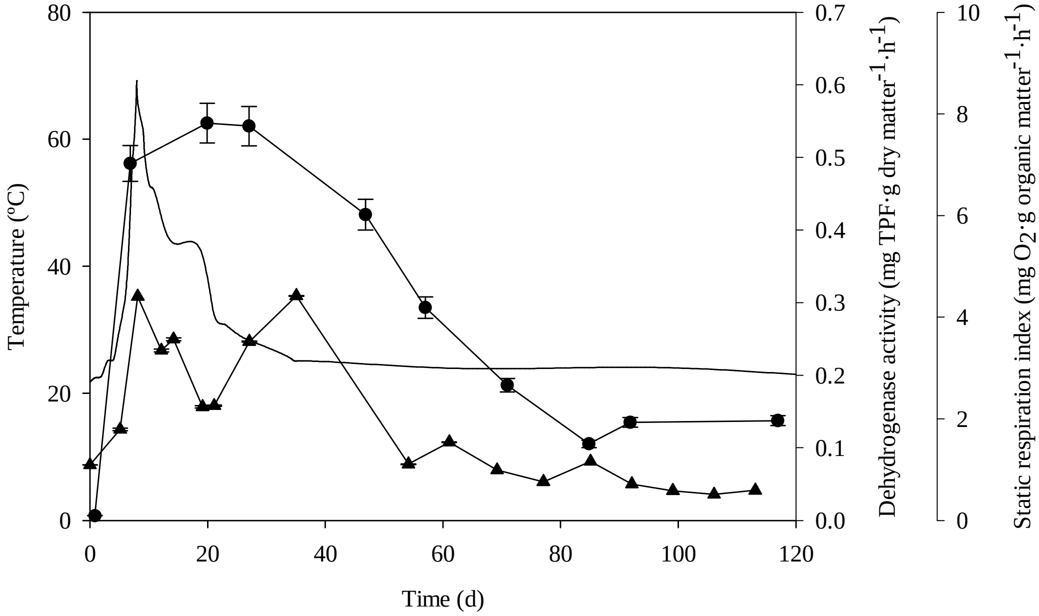

Figure 2: Barrena *et al*.