Available online at www.sciencedirect.com
ScienceDirect
Chemosphere 70 (2008) 436–444
CHEMOSPHERE
www.elsevier.com/locate/chemosphere

The evaluation of stability and maturity during the composting of cattle manure

María Gómez-Brandón *, Cristina Lazcano, Jorge Domínguez

Departamento de Ecología y Biología Animal, Universidad de Vigo, Vigo E-36310, Spain

Received 27 February 2007; received in revised form 22 June 2007; accepted 26 June 2007
Available online 8 August 2007

Abstract

We examined chemical, microbiological and biochemical parameters in order to assess their effectiveness as stability and maturity indicators during the composting process of cattle manure. The composting material obtained after 15 d in trenches and at different times during the maturation phase (i.e. 80, 180 and 270 d) were analyzed. We found that the material collected at the end of the active phase was inadequate to be applied to soil as organic amendment due to its high content of NH_4^+, its high level of phytotoxicity and the low degree of organic matter stability. After a maturation period of 80 d, the stability of the sample increased. This was shown by a reduction in the dissolved organic carbon (DOC) content and NH_4^+ concentration and also by a reduction in the microbial activity and biomass; however, 180 d of composting were not sufficient to reduce the phytotoxicity to levels consistent for a safe soil application. Among the various parameters studied, the change in DOC with composting time gave a good indication of stability.

Keywords: DOC; Mineral N; Microbial biomass; Basal respiration; Enzymatic activities; Phytotoxicity

1. Introduction

Cattle manure is a valuable resource as a soil fertilizer, providing a high content of macro- and micronutrients for crop growth, and represents a low-cost alternative to mineral fertilizers (Sharpley and Smith, 1995). However, the overproduction of organic wastes by cattle breeding has led to inappropriate disposal practices; for example, their indiscriminate application to agricultural fields and their improper timing of application, that is, they are not applied when it would be most beneficial for crops. These practices could cause serious environmental problems that could include an excessive input of potentially harmful trace metals, inorganic salts and pathogens (Hutchison et al., 2005); an increase in nutrient loss from soils through leaching, erosion and runoff due to not considering the nutrient requirements of crops (Vervoort et al., 1998); and the emission of hydrogen sulphide, ammonia and other toxic gases (Salazar et al., 2005).

The composting process may significantly reduce the environmental problems associated with the management of manures by transforming them into a safer and more stabilized material for application to soil (Carr et al., 1995). To obtain high quality compost it is necessary to understand the changes that the material undergoes with the composting process. The stability and maturity of the compost are essential for its successful application, particularly for composts used in high value horticultural crops (Wang et al., 2004).

The terms stability and maturity are usually used interchangeably to describe the degree of decomposition and transformation of the organic matter in compost (Zmora-Nahum et al., 2005), despite the fact they describe different properties of the composting substrate. Stability is strongly related to the rate of microbial activity in compost, and is evaluated by different respirometric measurements (Lasaridi and Stentiford, 1998) and/or by studying the transformations in the chemical characteristics of compost organic

* Corresponding author. Tel.: +34 986 812593; fax: +34 986 812556.
E-mail address: mariagomez@uvigo.es (M. Gómez-Brandón).

0045-6535/$ - see front matter
doi:10.1016/j.chemosphere.2007.06.065

matter (Pichler and Kögel-Knabner, 2000). Respirometric tests have been shown to be adequate for assessing compost stability because they are able to measure the extent of which readily biodegradable organic matter has decomposed during the composting process (Adani et al., 2004). Compost maturity generally refers to the degree of decomposition of phytotoxic organic substances produced during the active composting phase and to the absence of pathogens and viable weed seeds (Wu et al., 2000). Both these properties are critical for the quality and marketability of the final product.

The application of unstable compost to soil may produce a competition for oxygen between microbial biomass and plant roots/seeds. This fact can deprive plant roots/seeds of oxygen, and lead to the production of H_2S and NO_2^- (Mathur et al., 1993). Another problem is nitrogen starvation of plants as microorganisms scavenge soil N to make up for the deficit resulting from the application of unstable compost with a high C to N ratio. The phytotoxicity of unstable composts represents another major problem; this is due to the emission of ammonia and the presence of other phytotoxic substances like phenolic compounds and ethylene oxide that is synthesized during the decomposition of unstable compost in soil. Low-molecular weight organic acids (i.e. acetic, propionic and butyric acids) produced by the anaerobic digestion of the organic matrix are also responsible for compost phytotoxicity (Fuchs, 2002).

Management of the composting process must consider the potential agronomic value of the end product and its suitability for plant crops by evaluating its degree of maturity. Biological methods involving seed germination tests and plant growth bioassays have been used to evaluate the maturity of compost (Cooperband et al., 2003). This is a tedious work and there are disagreements regarding the ability of these tests to determine compost maturity (Brewer and Sullivan, 2003).

A large variety of techniques have been reported for the determination of compost stability (Wang et al., 2004). Chemical parameters such as pH, electrical conductivity (EC), cation exchange capacity, dissolved organic carbon (DOC) and the ratios of C to N and NH_4^+ to NO_3^- have been applied as indicators of stability. Since stabilization implies the formation of humic-like substances, humification indexes are generally accepted as a criterion of stability, but their absolute values vary greatly among composts of different source materials. Moreover, their determination requires proper separation of the non-humic fraction from the fulvic acid fraction because other compounds with similar structure to humic substances but different biological meaning (i.e. lignin residues, quinones, polyphenols, fats, etc.) can be extracted (Sánchez-Monedero et al., 1999). Stability indicators based on the study of microbial biomass and its activity have also been proposed. Mondini et al. (2006) reported that microbial biomass can be used as a stability parameter in ligno-cellulosic waste composts because it clearly reflects the transformation of organic matter during the composting process. Respiration (CO_2 evolution rate and/or O_2 uptake rate) is a general measure of microbial activity, and it has been widely used to evaluate the stability of compost (Gómez et al., 2006). The ATP content and enzyme activities are also useful as indicators of compost stability (Tiquia et al., 2002; Boulter-Bitzer et al., 2006).

The use of different parameters appropriate to determine the maturity and/or stability of composts will allow us to broaden our knowledge about the composting process. Therefore, the two major objectives of this study were (a) to describe the chemical, microbiological and biochemical changes during the industrial composting of cattle manure and (b) to compare different parameters with respect to their ability to evaluate compost stability and maturity during the industrial composting of cattle manure.

2. Materials and methods

2.1. Source materials and composting process

This study followed the composting process of fresh cattle manure obtained from the agricultural cattle complex "Energía Viva, S.A." in León, Spain. The researchers did not control the composting operation or attempt to influence the course of the composting process, which involved an active phase of 15 d, followed by a maturation stage in piles for 270 d.

Cattle manure subject to the active phase in five trenches with approximate dimensions of 42 m long, 1.8 m wide and 4.5 m high where each contained approximately 300 m^3 of material. Throughout the process, these trenches were aerated from the bottom with forced air through a blower in order to induce air convection movement into the material and deliver oxygen to microorganisms. The functioning of the air blower varied as a function of the temperature: (i) continuous aeration when the temperature of the composting mass overcame the value of 60 °C; (ii) intermittent aeration according to a preset cycle of 5 min aeration and 5 min pause when the temperature was found between 55 °C and 60 °C; and (iii) intermittent aeration according to a preset cycle of 5 min aeration followed by 10 min pause when the temperature was below 55 °C. The forced ventilation was combined with daily turnings in order to homogenize the composting mass and to avoid the substrate compaction and the subsequent low porosity and deficient air distribution. The composting material was watered with water and the moisture content was controlled daily and kept within the range of recommended values (45–65%; Miller, 1993).

During the curing phase, the composting mixture from each trench was pilled up and left to mature in maturation piles (50 m long, 2 m wide and 2 m high) up to 270 d in a space covered on top by a ceiling with the sides opened. These piles were turned for aeration twice a month and sporadically watered with leachates from the cattle farm. Samples were collected at 10 random locations at 15, 80,