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Environmental assessment of two home composts with high and low gaseous emissions of the composting process

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ABSTRACT

A Life Cycle Assessment (LCA) of two home composts with low and high gaseous emissions of the composting process is presented. The study focused on the gaseous emissions of the composting process. Gaseous emissions of methane, nitrous oxides, ammonia and volatic organic compounds of the composting process were experimentally measured in field real trials. The results showed that the differences in gaseous emissions between the two home composts were 4.5, 5.8 and 52 for methane, nitrous oxides and ammonia, respectively. Higher emissions of nitrous oxides and methane affected significantly the category of global warming potential, while higher emissions of ammonia affected mainly the categories of acidification potential, eutrophication potential and photochemical oxidation. The differences found in the compost emissions were attributable to the composting production management (quality and composition of waste stream, frequency mixing of waste, humidity and temperature monitoring, among others) as well as weather conditions (temperature and humidity).

1. Introduction

Currently approximately 40% of biowaste ends up in landfills in the European Union countries (Eurostat, 2010), despite the introduction of the landfill directive in 1999. One alternative, or rather complimentary, technology for the treatment of organic household waste (OHW) is home composting. In home composting, the OHW is taken out of the waste stream at the source, thereby lowering the amount of waste in the municipal waste stream (Andersen et al., 2012). The OHW is a fraction from the organic municipal solid waste.

Furthermore, composting is seeing as a good alternative to be used as mineral fertilizer substitute in horticultural. The management of the organic waste fraction of municipal solid waste is a growing problem due to the rapid collapse of landfills (Colón et al., 2010). To address this problem, the European Waste Framework Directive 1999/31/CE (Council of the European Union, 1999) states the reduction of the biodegradable waste being dumped to minimize environmental impacts and the loss of organic resources. Composting, which can be defined as the biological decomposition and stabilization of organic waste under controlled, thermophilic and aerobic conditions, is one of the most frequently alternatives to landfill (Haug, 1993; European Commission, 2008). Furthermore, the use of compost in agriculture not only reduces the total amount of waste being dumped but also contributes to eliminate most of the pathogenic microorganisms and reduces odor compounds obtaining a valuable product named compost. Thus, the use of compost in agriculture represents a sustainable way for the treatment of biowaste from the municipal solid waste.

Composting is the process in which the organic matter is degraded and stabilized by means of aerobic microorganisms, resulting in a final product (compost) free of pathogens and seeds. Many factors determine the quality of compost (i.e. waste stream composition, production management and weather conditions). While some, such as precipitation and ambient temperature, are clearly beyond the control of compost producers, although many other factors can be managed with proper planning. Some of these factors, for example, include type of equipment used for turning the compostable material, frequency of turning, quantities and/or ratios of feedstocks, and composting method. Understanding the

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interactions and trade-offs associated with such factors will help compost managers adjust the quality and consistency of their compost.

In the case of the Organic Fraction of Municipal Solid Wastes (OFMSW) the composting process can be done at industrial or at home scale. The benefit of self-managing process (i.e. compost) for the OFMSW from an environmental point of view is the reduction of the need of waste collection and transport thus avoiding fuel consumption and gaseous emissions (Lleó et al., 2013). However, home composting is not free of environmental impact. The physico-chemical and biological characteristics, the heavy metals content (Zn, Cu. Ni, Cr, Pb and Cd) in the final product as well as the gaseous emissions (CH_4, NH_3, N_2O and VOCs) of the composting process play an important role in the agronomical and environmental performance of the systems in which the compost is applied.

Home composting represents an alternative to central composting, especially in areas with low density population (Martínez-Blanco et al., 2010). The most important contribution in the term of environmental benefits and burdens of home composting have been identified as being the GHG emissions occurring during home composting and the actual substitution of peat and fertiliser when the compost is used in soil (Andersen et al., 2012).

Several studies of home composting have been found in literature to different purposes. These studies are mainly focused on the emissions occurred in the composting process (Amlinger et al., 2008; Andersen et al., 2012; Bernstad and la Cour Jansen, 2011; Boldrin et al., 2009; Chan et al., 2011; Ermolaev et al., 2014; Lundie, 2005) and the environmental assessment of home composting regarding other technologies and its application in crops (Colón et al., 2010; Martínez-Blanco et al., 2010; Lleó et al., 2013; Quirós et al., 2014).

A critical issue in the composting is the management of the home composting process to guarantee a quality product to be used as organic fertilizer or soil amendment. The application of good composting practices in which conditions are regulated and optimized, so that composting microorganisms can thrive, ensure a faster process and the generation of a quality end product. These management practices starts from the compost material preparation and ends with the finished compost, including how to determine the best mixed of feedstock materials, how to manage composter box for good aeration, how to manage pile moisture and odor, and how to check the finish products. Compost mixed should be based on feedstock properties such as C:N ratios, moisture content, bulk density, and particle size. Another important issue to consider is the good aeration of the composting to offer the environmental conditions for the aerobic microbe activity. As microbial activity increases in the composter, the microbes will consume more oxygen. If the oxygen supply is not replenished, composting can shift to anaerobic decomposition, thus slowing the rate of the composting process and leading to foul odors, between others. "Stability of the final compost is a key factor in order to consider this material as a suitable material for soil amendment or as a mineral fertilizer substitute. Compost stabilized implies that biodegradable waste has been properly degraded by the action of microorganisms which implies a low microbiological activity. Stability of the final compost is a key factor in order to consider compost as a suitable material for soil amendment or as a mineral fertilizer substitute. Compost stabilized implies that biodegradable waste has been properly degraded by the action of microorganisms which implies a low microbiological activity. Stabilized or matured compost is a sign of good quality compost. The good quality is related to several benefits when it is applied in soil (i.e. odors prevention and low emissions to air and water). Biological activity can be determined by using the Dynamic Respiration Index (DRI) (Gea et al., 2004). DRI is expressed as milligram of oxygen consumed per gram of organic matter (OM) and per hour ($mg\,O_2\,g^{-1}\,OM\,h^{-1}$). This measure is related to the biodegradable OM present in the sample and it is widely used in the scientific literature (Colón et al., 2012). European Commission (2001) sets the parameter of 0.5–1.0 $mg\,O_2\,g^{-1}\,OM\,h^{-1}$ to consider the compost as stable material.

Regarding the benefits of compost, several advantages of the use compost in agriculture have being pointed by Martínez-Blanco et al. (2013). The benefits are summarized by nine main indicators: improve nutrient supply in soil; a way for the carbon sequestration; weed, pest and disease suppression; increase the crop yield; positive effect in the soil moisture content; soil workability; soil biological properties and biodiversity; and crop nutritional quality.

The aim of this LCA is to compare two home composts (i.e. with high and low emissions) to observe the consequences of the gaseous emissions of the composting process in the environmental performance of horticultural systems. Due to time and land preparation issues and material availability (i.e. compost with low emissions), only the HC-HE was applied to horticultural cauliflower crops

2. Materials and methods

This section presents a description of the experimental conditions and the methodology (LCA) to do the environmental assessment.

2.1. Experimental condition of compost application in cauliflower crop

The experimental field was located at the IRTA (Institut de Recerca i Tecnologia Agroalimentàries) research center in Maresme county, Santa Susana (NE of Catalonia). The Maresme county is a region characterized by an intensive crop rotation of several agricultural products (i.e. vegetables). The cauliflowers (*Brassica oleracea var. Trevi*) were transplanted at a plant density of 2.1 plants m^{-2}. The experimental design of the field pilot included one plot of 39 m^2. The compost application was on September 21, 2011; the cauliflower was transplanted from the nursery to the plots on October 5, 2011; and the harvest was conducted from February 1 to 8, 2012. More details of the experimental conditions can be seen in Quirós et al. (2014).

2.2. Life Cycle Assessment methodology

This research was developed according to Life Cycle Assessment (LCA) methodology from ISO 14044 (ISO, 2006). LCA is a methodology for determining the environmental impacts associated with a product, process or service from cradle to grave. The SimaPro v. 7.3.3 software (PRé Consultants, 2012) was used to determine the environmental impacts. The impact assessment was made following the CML 2001 methodology guidelines. The CML 2001 methodology was developed by the Centre of Environmental Science of Leiden University (Guinée, 2001). The impact categories selected for this study were the following: abiotic depletion potential (ADP), acidification potential (AP), eutrophication potential (EP), global warming potential (GWP), ozone layer depletion potential (OLDP), photochemical oxidation potential (POP) and an energy flow indicator, cumulative energy demand (CED).

2.2.1. Goal and functional unit

The aim of this LCA is to compare two home composts (i.e. with high and low emissions) to observe the consequences of the gaseous emissions of the composting process in the environmental performance of horticultural systems. Due to time and land preparation issues and material availability (i.e. compost with low emissions), only the HC-HE was applied to horticultural cauliflower crops.