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Improvement of home composting process of food waste using different minerals

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A B S T R A C T

This article presents the experimental study of the process of composting in a prototype home-scale system with a special focus on process improvement by using different additives (i.e. woodchips, perlite, vermiculite and zeolite). The interventions with different bulking agents were realized through composting cycles using substrates with 10% additives in specific mixtures of kitchen waste materials. The preselected proportion of the mixtures examined was 3:1:1 in cellulosic:proteins:carbohydrates, in order to achieve an initial C/N ratio equal to 30. The control of the initial properties of the examined substrates aimed at the consequent improvement of the properties of the final product (compost). The results indicated that composting process was enhanced with the use of additives and especially the case of zeolite and perlite provided the best results, in terms of efficient temperature evolution (>55 °C for 4 consecutive days). Carbon to nitrogen ratios decreased by 40% from the initial values for the reactors were minerals were added, while for the bioreactor tested with woodchips the reduction was slight, showing slowest degradation rate. Moisture content of produced compost varied within the range of 55–64% d.m., while nutrient content (K, Na, Ca, Mg) was in accordance with the limit values reported in literature. Finally, the composts obtained, exhibited a satisfactory degree of maturity, fulfilling the criterion related to the absence of phytotoxic compounds.

1. Introduction

Even though composting, from home-scale to larger-scale applications, is a well-established technology in the majority of Europe and other developed countries of the world, for the case of Greece, the existing situation is quite different. In general, the trend of the last decades has been the design, construction and operation of centralized, large waste treatment and disposal facilities. However, large infrastructure projects involve increased collection, transportation and operational costs in order to cover the waste management needs at regional level.

Across Greece, in large-scale applications, mainly Mechanical Biological Treatment (MBT) Plants, composting has been the main method for organic waste treatment coming from mixed waste collection. This means that the final product (Compost Like Outpur – CLO) has a questionable quality (Malamis et al., 2017) and lower value compared to compost derived from separate collection of biowaste. Due to this low quality, CLO potential applications to land are limited to lower grade solutions such as rehabilitation of brownfield sites or landfill cover (WASTE-C-CONTROL, 2011).

Furthermore, regarding home composting in Greece, the existing situation, up to the present, includes scattered, yet worthy to mention, initiatives and voluntary, pilot schemes applied in Municipalities. These initiatives comprise local-scale programmes for source separation and composting of biowaste using either domestic composting systems (LIFE WASP Tool, 2011–2014; LIFE HECPAYT, 2009–2011; LIFE COMWASTE, 2003–2006), community-scale systems (LIFE ISWM – TINOS, 2011–2015) or even a centralized composting facility (Athens-Biowaste, 2011–2014).

The estimates published from the Ministry of Environment, Energy and Climate Change of Greece (MEECC GR) (2013), reveal a very low recovery rate (~3–4%) of the organic fraction of Municipal Solid Waste (MSW). The diverted quantities of organic waste from landfills result from: (i) biowaste treatment in domestic composting bins (i.e. 10,000 tonnes/year) (BiPRO, 2013), (ii) centralized MBT facilities (i.e. 68,139 tonnes/year) and (iii) diversion of organic waste in rural areas (i.e. 81,144 tonnes/year) through home composting or valorization of food waste for animal feed (MEECC GR, 2013). In Greece, biowaste is the biggest fraction of MSW, accounting for 44% per weight of the total MSW produced. Still in Greece, more than 80% of generated MSW are sent to landfills and until

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recently there was not a national strategy in place to address the sustainable management of biowaste.

Efforts for a shift towards more sustainable practices for waste treatment, and in particular biowaste, are expected to be triggered with the regulatory changes applied since 2015. More specifically, the recently revised National Waste Management Plan (NWMP) which was officially approved by the Ministerial Act 49 of 15.12.2015, along with the National Strategic Waste Prevention Plan, regard the biowaste fraction as a high priority waste stream. In particular, on the basis of the provisions and guidelines of the new NWMP, source separation is indicated as the most appropriate method for efficient waste collection and an effective driver for the achievement of higher levels of recycling. Therefore, the national plan sets the target of separate biowaste collection of 40% by weight to be reached by 2020. This ambitious target is foreseen to be achieved by promotion of on-site diversion of organic household waste in rural areas for direct use as animal feed and promotion of decentralized, community-scale composting facilities in almost each municipality or agglomeration of municipalities. Moreover, with this NWMP, home composting is considered not as a waste prevention measure, but as a recycling activity. Furthermore, what is worth mentioning is that for the first time a target of minimum 3% biowaste diversion through home composting is also set to be reached by 2020, at national level (Ministry of Environment and Energy of Greece, 2015).

The present work addresses the topic of home composting, which is considered a sustainable method for household biowaste treatment, where biowaste are separated at source in order to produce high quality compost. By this way, biowaste are treated and valorized on-site, enhancing the soil quality locally and are diverted effectively from landfills (Li et al., 2013). Home composting may also become a reliable alternative solution for low-density urban or rural areas that require high transportation costs for the separate collection of biodegradable household waste to central treatment facilities (Martínez-Blanco et al., 2010; Tatàno et al., 2015). Nevertheless, home composting presents a few disadvantages such as the fact that the finished compost may not be homogeneous at the end of the process and during the biological degradation, there could be odors, making householders discouraged from practicing, while gaseous pollutants are also produced (Madrini et al., 2016). The air pollutants may be comprised of methane, ammonia and nitrous oxide thus, contributing to the negative impacts of climate change (Martínez-Blanco et al., 2010; Amlinger, et al., 2008; Ansorena, 2008).

The characteristics of the initial substrate also affect the efficiency of the process by acting on ventilation conditions and the diffusion of oxygen in the organic mass. These properties include the porosity, size, structure and texture of the substrate particles (EA, 2001). In most cases, the control of the physical properties of the substrate is achieved through pre-treatment processes such as crushing, granulation and cutting, as well as the selection and mixing of suitable bulking agents. The use of bulking agents is made in order to ensure the necessary structure and porosity of the mixture and additionally adjust the C/N in the original substrate (Iqbal and Shafiq, 2010).

Several studies have addressed the optimization of the composting process using various bulking agents. The additives which are most frequently encountered in literature are the wood shavings, sawdust, leaves, branches and tree barks, coal fly ash, bauxite, natural zeolites, and kaoline, bentonite, wood ash, residues from cereal, straw, rice husks, lime, phosphogypsum, polyethylene, glycol, jaggery etc. (Gabhane et al., 2012; Li et al., 2012; Kurola et al., 2011; Villaseñor et al., 2011; Zambrano et al., 2010; Adhikari et al., 2009; Bernal et al., 2009; Belyaeva and Haynes, 2009). However, there is a limited number of papers that perform a comparative assessment of the effect of minerals in the composting of various organic waste substrates, since the focus is usually on the influence of an individual additive in composting, what is more, a significant number of studies is mainly centered on the case of zeolite (Madrini et al., 2016; Li and Li, 2015; Latifah et al., 2015; Stylianou et al., 2008; Witter and Lopez-Real, 1988). Even fewer studies have performed comparative studies of the composting process of kitchen waste substrates with minerals in small-scale systems for household use. Finally, a distinctive point of the present work is that the bioreactors used for the present experimental study are prototype systems, no available in the market, which were designed and constructed by the Unit of Environmental Science and Technology of the School of Chemical Engineering of the National Technical University of Athens, Greece.

The objective and the innovative approach of the presented work was to perform a comparative study of the effect of four different additives (i.e. woodchips, perlite, vermiculite and zeolite) in the composting process. For this reason, organic substrates from source-separated kitchen waste were formed in fixed proportions of proteins – carbohydrates and – cellulosic food waste, and 10% additives, so as to achieve pre-determined initial properties. The effectiveness of the composting process was evaluated by analyzing a wide range of physico-chemical parameters of the intermediate substrates and the final products (including also phytotoxicity tests).

2. Material and methods

2.1. Description of the prototype household composting bioreactors

For the implementation of this research, an prototype household composter was used. The innovative technical and operational characteristics of the prototype system for home composting have been described in detail in the study of Papadopoulos et al. (2009). More specifically, the prototype system is a closed type fed-batch bioreactor. The input of feed material and the mechanical mixing/-stirring are performed manually. The processing capacity of the system is 60 Ls/week of organic material. The bioreactor consists of four individual and segregated compartments, namely (i) the feeding compartment, (ii) the composting process compartment, (iii) the compartment for the collection and removal of compost and (iv) the compartment for the collection and removal of produced leachate (Fig. 1).

For the experimental study, four prototype bioreactors were used simultaneously to conduct the monitoring and evaluation of the composting process of household organic substrates mixed with zeolite, vermiculite, perlite or wood chips. For comparison reasons, an additional bioreactor, containing no additives, just source-separated biowaste, was used as 'blank' for the monitoring of the composting process and the initial evaluation of the performance of the prototype bioreactor. The results of the monitoring are included in the graphs depicting the evolution of basic operational parameters i.e. pH and TOC over time respectively. The reference bioreactor confirmed that without additives the biodegradation cannot occur efficiently due to high moisture levels of the substrate and no adequate oxygen level, resulting in the development of anaerobic conditions and foul odours (Sundberg, 2005).

2.2. Substrate material

The material used for the composting process, consisted of separately collected biowaste from households of Kifissia Municipality in Attika, Greece. The additives employed in this study were zeolite, vermiculite, perlite and wood chips. Natural zeolite, vermiculite and perlite were purchased by relevant companies. Wood