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Home and vermicomposting as sustainable options for biowaste management

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Abstract

Home composting (also known as backyard composting) presents some potential benefits for the industrial treatment of the organic fraction of municipal solid waste or biowaste. Home composting avoids the collection of biowaste, reduces the impurities present in the waste being treated and, consequently, in the resulting compost, and theoretically decreases the material and energy needs of the process. However, self-composting requires a composting bin and pruning waste as bulking material as well as space in a garden or on a roof that is not always available. An alternative for the self-management of biowaste is vermicomposting, which requires less space and no bulking material. Both the home composting and vermicomposting methods were studied over an eight-month period to determine the quality of the compost produced, the capacity of the methodology and the resulting gaseous emissions. The treatment capacity of the composters used in this work was determined on a weekly basis. The vermicomposter had a treatment capacity of 50 g biowaste per L, whereas the home composter had a treatment capacity of 16 g biowaste per L. The home composter required the addition of 6.3 g of bulking agent per L of composter. The quality of the final product, compost, was similar in both cases, with each batch of compost having low metal content and a high degree of stability, with Dynamic Respiration Indices of 0.43 and 0.89 mg O₂ g⁻¹ Organic Matter h⁻¹ for compost and vermicompost, respectively. Gaseous emissions from home composters show the presence of 1.3 kg NH₃ Mg⁻¹ biowaste and 1.35 kg CH₄ Mg⁻¹ biowaste, values that are within the range reported in the literature for home and industrial composting, although N₂O emissions, 1.16 kg Mg⁻¹ biowaste, were higher. Gaseous emissions from the vermicomposters were lower than from the home composters: 3.33·10⁻³, 2.19·10⁻³ and 3.66·10⁻³ kg of pollutant Mg⁻¹ biowaste for NH₃, CH₄ and volatile organic compounds, respectively. No odours were detected for either system. Home and vermicomposting can be considered suitable alternatives to divert a portion of the biowaste from the traditional waste management system.

Keywords: Home composting, Compost quality, Gaseous emissions, OFMSW, Treatment capacity, Vermicomposting.

1. Introduction

The Landfill Directive published in 1999 by the European Union (Council of the European Union, 1999) requires its Member States to reduce the quantity of biodegradable waste ending up untreated in landfill sites by adopting measures to increase and improve waste reduction, recovery and recycling. Reduced landfilling in favour of increased recycling of materials (glass, paper and cardboard, plastic, metals and organic fraction) seems to lead to lower environmental impact and lower energy demand (Eriksson et al., 2005). For the organic fraction of municipal solid waste (OFMSW) or biowaste, separation at the source and treatment through composting and/or anaerobic digestion appear to be the most sustainable options (European Commission, 2008). Composting, defined as the biological degradation and stabilisation of organic substrates under controlled thermophilic and aerobic conditions (Haug, 1993), leads to the production of quality compost that can be used as an organic addition to soil in agriculture. In addition to its fertilising effects, compost improves the physical properties of soil by increasing its capacity to retain water and supply organic nutrients (Hargreaves et al., 2008).

The composting process of OFMSW has been developed and studied on the industrial scale from both technical and environmental perspectives (Amlinger et al., 2008; Blengini, 2008; Colón et al., 2012; Ruggieri et al., 2008). The consumption of energy for waste transport and processing, the mixture of materials of different quality, the emission of odours and other contaminants, and public acceptance have been identified as the main concerns regarding composting (Blengini et al., 2008). Specifically, Colón et al. (2012) reported emission factors for different gaseous pollutants for industrial and home composting depending on the technology used: 0.11–8.6 kg NH₃ Mg⁻¹ OFMSW, 0.36–6.22 kg VOCs (volatile organic compounds) Mg⁻¹ OFMSW, 0.34–4.37 kg CH₄ Mg⁻¹ OFMSW and 0.075–0.251 kg N₂O Mg⁻¹ OFMSW. Colón et al. (2012) also calculated the energy and water needs for the full-scale plants within the study, with calculated values ranging from 235 to 870 MJ Mg⁻¹ OFMSW and from 0 to 0.5 m³ water Mg⁻¹ OFMSW, respectively.

On a small scale, composting can be developed for the home using processes that have not been studied extensively from a technical and scientific perspective (Amlinger et al., 2008; Andersen et al., 2011; Chanaykya et al., 2007; Colón et al., 2010). Home composting, traditionally considered a horticultural recreational activity, has been highlighted as a potential major diversion route for OFMSW (Andersen et al., 2011) because home composting presents some potential benefits relative to industrial composting. Home composting avoids the collection of an important portion of municipal solid wastes, reducing the economic, material and energy investment in infrastructure (Ligon and Garland, 1998). For instance, transport energy needs for industrial composting are 18.6-fold the energy needs for home composting, as reported by Martínez-Blanco et al. (2010), when considering the complete life-cycle of the two processes. Home composting also requires less land use and allows more specific control of the composting process and the organic material treated. However, the home composting of OFMSW also presents some concerns. Food scraps and garden wastes have slow decomposition rates that can result in bad odours and attract flies and rodents (Chanaykya et al., 2007). Other studies have noted that, during home composting, gaseous pollutants such as ammonia, methane and nitrous oxide are emitted to the atmosphere. Amlinger et al. (2008) reported values for ammonia emissions ranging from 0.474 to 0.972 kg Mg⁻¹ OFMSW and from 0.192 to 0.454 kg Mg⁻¹ OFMSW for N₂O. Andersen et al. (2010) estimated CH₄ and N₂O emissions in the range 0.4–4.2 and 0.3–0.55 kg Mg⁻¹ OFMSW, respectively, whereas Martínez-Blanco et al. (2010) determined a set of emission factors of 0.842 kg NH₃ Mg⁻¹ OFMSW, 0.158 kg CH₄ Mg⁻¹ OFMSW and 0.676 kg N₂O Mg⁻¹ OFMSW. Andersen et al. (2011) report the highest emissions in frequently mixed (weekly) composting bins as well as a direct relationship between composter waste load and gaseous emissions. Other aspects of concern are the need for adequate open place to install the composting bins and for the necessary amount of bulking material to provide the adequate porosity and moisture control that the process requires (Ruggieri et al., 2009).

Vermicomposting on the home scale could be an alternative when space restrictions are a concern. Vermicomposting involves the stabilisation of organic solid wastes through

consumption by earthworms that convert the waste into earthworm castings (vermicasts). In fact, vermicomposting is the result of combined activity by microorganisms and earthworms (Singh et al., 2011) although earthworms are the main drivers of the process (Lazcano et al., 2008). The vermicast obtained at the end of the process is rich in plant nutrients and is free of pathogenic organisms (Singh et al., 2011). Several earthworm species are suitable for the treatment of OFMSW, with *Eisenia andrei* and *Eisenia foetida* being the most commonly used (Khwairakpam and Bhargava, 2009). Although not widely implemented on the industrial scale, vermicomposting has been reported to be an adequate technique for the treatment of different organic wastes including sewage sludge, agro-industrial wastes and sludge, cattle manure and urban solid wastes (Elvira et al., 1998; Garg et al., 2006; Hait and Tare, 2012; Kwon et al., 2009; Lazcano et al., 2008; Singh et al., 2011). The action of earthworms breaking down the substrate accelerates the rate of decomposition. The temperature regime during the vermicomposting process is always in the mesophilic range, which does not ensure the removal of pathogenic microorganisms, although some studies have shown that the final product is hygienic (Lazcano et al., 2008). This problem is one of the drawbacks of industrial-scale implementation of the vermicomposting process.

Singh et al. (2011) presented a detailed review on the integration of the vermicomposting process in a municipal solid waste management system and highlighted its main benefits. These authors emphasise that vermicomposting is odourless, cost effective, produces a product with better nutrient availability than traditional composting, leads to the destruction of pathogenic microorganisms, and results in low greenhouse gas emissions. However, no scientific studies of the vermicomposting process on the home scale, as an alternative to traditional waste management systems, taking into consideration capacity, gaseous emissions and product quality, have been undertaken to date.

Home and vermicomposting have been proposed as alternative treatments when discussing sustainable food waste management options (Barnes and Jerman, 2002; Lundie and Peters, 2005). Life Cycle Assessment (LCA) is commonly applied in these studies, but the small amount of data available regarding the environmental loads derived from the treatment

processes (such as gaseous emissions or capacity) is source of uncertainty (Rigamonti et al., 2010).

The objective of this work is to evaluate composting and vermicomposting as alternatives for the self-management of OFMSW in terms of the amount of waste that can be diverted from centralised waste management systems, the evaluation of the quality of the end product, the space and time requirements, and potential management problems. Ammonia, VOCs, methane and nitrous oxide emissions were also monitored for the two treatment options as indicators of the environmental impact of both options.

2. Material and methods

2.1 Organic materials

The material fed to the composting bin was composed of leftovers of fruit and vegetables, which is the material recommended for home composting. This material was obtained from a local shop and from Mercabarna, the Barcelona city market supplier (Barcelona, Spain). Additionally, a small amount of cooked pasta, rice and bread was added to the vermicomposter (up to 33% of the total waste fed) to simulate the complete composition of OFMSW. Pruning waste (PW) was obtained from a municipal waste treatment plant and from Barcelona city pruning operations and used as the bulking agent in the composting bin. The characteristics of these materials are summarised in Table 1.

2.2 Experimental procedure

Three home composters were used in the experiment and placed outdoors in the Department of Chemical Engineering of the *Universitat Autònoma de Barcelona* (Mediterranean region) in open shady conditions on a paved surface and were operated from November 2010 to June 2011.

The composting bins used (0.6 m x 0.6 m x 0.8 m) were made of recycled plastic. They had a capacity of 300 L and a weight of 18 kg and were supplied by Compostadores SL (model Combox 300 Barcelona; Figure 1a). The composters had a lateral system for natural ventilation

to guarantee aerobic conditions. The organic matter was poured into the upper part of the composter, and compost was extracted through the lower panels.

To start the experiment, the composting bins were half-filled with a mixture of OFMSW and PW (1:1, v:v). After the initial filling, the home composters were fed twice a week, with a total weekly amount of 4.7 kg of OFMSW and 1.9 kg of PW. The OFMSW and PW were mixed before being poured into the composting bin. At each feed, the upper layers of material in the composters were mixed with a commercial tool specially constructed for this purpose (mixing tool, Compostadores SL, Barcelona, Spain). Feeding was suspended from week 7 to week 13 of the study to regulate the moisture content by increasing mixing and aeration of the material. The compost was extracted once at week 13 and again at the end of the experimental period.

A tray placed at the bottom of the composting bins allowed leachate collection, performed when needed (typically once a week).

The vermicomposter was placed indoors in a research laboratory of the Department of Chemical Engineering of the *Universitat Autònoma de Barcelona*, where the temperature was maintained between 15 and 20°C during the experiment. The vermicomposter (0.51 m diameter, 0.66 m height) was provided by Compostadores SL (model Can-O-Worms) and had a capacity of 40 L, with two trays to hold the material being decomposed and an additional bottom tray to collect leachate with a valve to remove the accumulated liquid. The vermicomposter was made of recycled polyethylene with a weight of 6.3 kg (Figure 1b).

To start the experiment, the earthworms (approximately 700) were mixed with humidified coconut fibre (both supplied alongside the vermicomposter) and 1 kg of OFMSW following the indications of the supplier. The vermicomposter was fed twice a week with a total of 1 kg of OFMSW. The quantity of OFMSW poured into the vermicomposter weekly was gradually increased to reach the optimum amount during the fifth week of the process (1.9 kg of OFMSW). Higher amounts were tested (up to 2 kg of OFMSW) but resulted in putrefaction odours owing to the inability of the earthworms to consume all of the organic matter. The decomposing material was mixed each time the vermicomposter was fed. A significant increase in the number and size of the earthworms was observed. After 6 weeks, the second tray of the

vermicomposter was used and started by adding approximately 25% of the content of the first tray. Leachate was collected on a weekly basis.

2.3 Analytical methods

Moisture and organic matter (OM) content, N-Kjeldahl, pH, electrical conductivity and heavy metal content of the materials and compost were determined following the standard methodology proposed by the US Department of Agriculture and the US Composting Council (2001).

The Dynamic Respiration Index (DRI) was determined following the methodology proposed by Adani et al. (2006). Details of the respirometer used can be found in Ponsá et al. (2010). DRI was used as a measure of the biological activity and stability of the material and expressed as mg of oxygen consumed per g of organic matter per hour ($\text{mg O}_2 \text{ g OM}^{-1} \text{ h}^{-1}$). DRI is calculated from the average value of 24 instantaneous respiration indices obtained during the most active 24 h of biological activity.

Transmission electron microscopy images of the end-product compost were obtained with a JEOL 1010 Transmission Electron Microscope (JEOL USA Inc., Peabody, MA, USA) operating at an accelerating voltage of 15 kV.

2.4 Gaseous emissions

The methodology developed by Colón et al. (2009) and Cadena et al. (2009) for the sampling and determination of gaseous emissions from industrial composting facilities was adapted to determine home-composter emissions (Colón et al., 2010). In brief, airflow velocity and ammonia, nitrous oxide, methane and VOC concentrations were recorded simultaneously on the material surface of the composter and used to calculate the gas emission rate (mg s^{-1}). The upper surface of the composting bin was measured (m^2) and considered the sole source of gaseous emissions. Air velocity was determined using a thermo-anemometer (VelociCalc Plus mod. 8386, TSI Airflow Instruments, UK) and a Venturi tube (Veeken et al., 2002). Ammonia concentration in the gaseous emissions was determined in situ using an ammonia sensor ITX

T82 with a measurement range of 0 to 200 ppm_v. Gaseous samples were also collected in Tedlar bags for the chromatographic determination of CH₄, N₂O and VOC following the methods detailed in Colón et al. (2012).

Airflow velocity could not be determined in the vermicomposter because flow rates were too low. The concentrations of the different pollutants were determined as stated above. Emission factors (kg of pollutant emitted Mg⁻¹ OFMSW) were estimated based on the DRI value, which determines the amount of oxygen consumed per hour per unit mass of waste and, consequently, the rate of airflow moving through the system required to provide sufficient oxygen. DRI values are converted into airflow values per kg OM (L h⁻¹ kg OM⁻¹) considering air molar composition (21% O₂) and a temperature of 20°C. Additionally, taking into account the OM content of OFMSW, the airflow values per kg OFMSW are finally obtained (m³ d⁻¹ kg⁻¹ OFMSW).

3. Results and discussion

3.1 Process requirements and capacity

The treatment capacity of the composters used in this work was determined on a weekly basis as a maximum of 50 g of OFMSW per L for the vermicomposter and as 16 g of OFMSW per L for the home composter, taking into account that 6.3 g of bulking agent per L was also fed to the home composter to regulate moisture content and porosity. At a lower OFMSW moisture content, the treatment capacity of the home composter could be higher. One of the drawbacks of home composting is the availability of adequate material to act as bulking agent, as bulking agent is not always available.

3.2 Evolution of process parameters and final product characteristics

An important reduction of the mass of the waste treated was observed for both processes. On a dry-weight basis, a 41% reduction was determined for the home composter, whereas the vermicomposter value reached 72%. These values were calculated on a total weight basis and included bulking agent for the home composter and coconut fibre for the vermicomposter.

The temperature of the vermicomposters was maintained at 15–20°C in the laboratory. The average temperature and ambient temperature as recorded for the home composters is shown in Figure 2. An increase in the temperature of the composting material, reaching 55°C, was observed only at the beginning of the process, when the composting bins were filled to half of their capacity to start the composting experiment. After the start of the composting experiment, ambient and process temperatures show similar profiles, with process temperatures peaking slightly after each waste addition.

The pH and electrical conductivity of the decomposing material increased with process time from 7.11 to 7.65 and from 1.25 to 3.29 mS cm⁻¹ for vermicomposting. The pH also increased in the home composters from 5.90 to 8.97, whereas conductivity decreased slightly from 1.85 to 1.72 mS cm⁻¹. Small volumes of leachate were collected in both cases. The electrical conductivity and pH of the leachate changed during the process time from 1.01 mS cm⁻¹ to 2.00 mS cm⁻¹ and from 7.3 to 7.9, respectively, for vermicomposting, and from 2.50 to 19.9 mS cm⁻¹ and from 5.25 to 8.50, respectively, for home composting.

The presence of insects and rodents has been associated with the composting process both on the industrial and home scale (Haug, 1993). Vinegar flies (*Drosophila melanogaster*) and ants were detected in the vermicomposter and in the home composters. Sack fabric was used to cover the upper part of the material decomposing in the home composters to decrease the presence of flies. A small glass containing vinegar and soap was placed in the centre of the upper tray of the vermicomposter and used as a fly trap. Both methods were effective, and the number of flies decreased significantly. No rodents were detected in the vicinity of the composters during the experiment.

A qualitative assessment of odours was performed during the experiment. In the case of vermicomposting, odours (putrefying food) occurred only when the maximum capacity of the bin was exceeded, and the earthworms were not capable of degrading the OFMSW efficiently. The presence of odours was an indicator of vermicomposter overloading. In the vicinity of the home composters (1.5–2 m distance), only 9 out of 64 times was the odour perceived as 2 on an odour scale of 0 to 3 (3 being an intense/annoying odour). The presence of fish and meat in

waste has been identified as a source of odours at home (Colón et al., 2010). Avoiding this type of waste can reduce the odour nuisance.

Table 2 presents the characteristics of the final products obtained from both methods studied (compost in the case of home composting and vermicast in the case of vermicomposting) and the compost quality standards for composts produced industrially (California Compost Quality Council, 2001; Giró, 1994; Real Decreto 824/2005). There are no standard values for products obtained at home, which are expected to be used in the producers' own gardens. The properties of the vermicast were found to be within the compost quality limits, except for moisture content, which exceeded the proposed values. This exceedance of moisture content is inherent to the process when the process is conducted on a small scale in a closed bin. Singh et al. (2011) report pH values for vermicast to be between 6.8 and 7.5 and nitrogen content in the range of 1.2–1.6%. Relative to the quality standards, the compost obtained has higher moisture content and pH value and slightly lower nitrogen content than the standard values. Regarding the respirometric index, both products show a high level of stability according to California Compost Quality Council (2001). Metal concentration was significantly under the lower limit values (corresponding to a Class A compost) in all cases, indicating an extremely low presence of metals. The careful selection of input materials when the process is run at home is responsible for this low concentration. The final products (compost and vermicast) were sanitary tested negative for *Salmonella* and *Escherichia coli* under the limits outlined in legislation.

The main difference observed between the two products is moisture content. Moisture content is crucial for a controlled evolution of the biodegradation process. The moisture content of the starting material fed to the process was in the range of 75–80%. In the case of vermicomposting, the aeration of the bin is minimal, and no heat is generated during the process, making moisture removal difficult and sometimes undesirable for the earthworms. The vermicomposter valve used for leachate removal was left in the open position to facilitate air circulation through the decomposing material. Despite all efforts, the moisture content of the material in the bin was 75–82%. In the case of home composting, the low ambient temperatures

and the fairly high levels of rainfall registered during the experiment, together with a small increase in the temperature of the composting mass, were responsible for the difficulties in moisture content regulation during the experiment. Although a bulking agent with low moisture content was added, this parameter could not be maintained within the recommended values for industrial composting during the process (40–60%, Haug, 1993). Recorded values ranged between 60 and 78%. Both processes involve biological activity, and proper organic matter stabilisation was observed from the DRI values of the final products that were lower than the proposed standards. Considering the DRI values of the initial waste reported in Table 1, 88% and 77% reductions were reached in home composting and vermicomposting, respectively.

Compost and vermicast present a very porous microstructure for the degraded homogeneous organic material (Figure 3). This porous structure of the organic material is valuable when the organic material is used as a soil conditioner because the porous organic material improves the structure of the soil and its ability to retain water. As shown in the right-hand side of Figure 3a and b, the vermicast has a higher porosity than home compost.

3.3 Gaseous emissions

Gaseous emissions were measured weekly for ammonia from week 13 onwards and for methane from week 16 to the end of the experiment for both home composting and vermicomposting. Data on N₂O emissions were collected for home composting from week 19 and VOC emissions for the vermicomposter from week 24. Because of operational difficulties, gaseous emissions were not measured during the start-up and first weeks of operation. However, the initial period was not considered representative of the whole composting process, and gaseous emissions reported in this work correspond to the steady operation of the process.

Table 3 summarises the maximum, minimum and average values found for the concentration of the different compounds. In the case of ammonia emissions, an oscillating behaviour was observed in home composting. No relationship could be established between the ambient and process temperatures or the feeding or mixing operations. The ammonia emissions were lower in the vermicomposter, and large fluctuations were not recorded. Values for VOC

concentration during vermicomposting show a constantly decreasing trend from 31 to 0 ppmv. No references on gaseous emissions from vermicomposting at home were available in the literature. VOC concentrations within 0–20 ppm in home composting gaseous emissions were found in other experiments (data not shown). Importantly, the greenhouse gas (CH_4 and N_2O) emission concentrations were in accordance with the values reported in Colón et al. (2010).

Emission factors (amount of pollutant emitted per mass of waste treated) were also calculated (Table 3) for NH_3 , CH_4 and N_2O in home composting resulting in $1.3 \text{ kg NH}_3 \text{ Mg}^{-1}$ OFMSW, $1.35 \text{ kg CH}_4 \text{ Mg}^{-1}$ OFMSW and $1.16 \text{ kg N}_2\text{O} \text{ Mg}^{-1}$ OFMSW. Ammonia and N_2O emission factor values in this work are higher than the values found in literature (Amlinger et al., 2008), whereas CH_4 emissions are within the range reported by Andersen et al. (2010) and higher than the values presented by Martínez-Blanco et al. (2010). All of these factors constitute an indication of anaerobic zones present in the composting mass. The high level of moisture in the home composters and the temperatures registered can also cause high N_2O emissions. Waste mixing and moisture adjustment can help to control and decrease the emissions of these pollutants. In comparison to the values reported for industrial facilities (Colón et al., 2012), NH_3 and CH_4 emissions are closer to the lower end of the concentration ranges reported, whereas N_2O values are higher.

The emission factors for vermicomposting could not be determined because the velocity of the gases emitted could not be determined. There was no aeration (forced or natural), and the airflow could not be measured in the vermicomposting bin. However, an estimation of the emission factors was performed based on the DRI value, which determines the amount of O_2 consumed per hour per unit of waste, and, consequently, the airflow necessary for the decomposition process in the system. Airflow was estimated as $1.13 \cdot 10^{-2} \text{ m}^3 \text{ kg OFMSW}^{-1} \text{ d}^{-1}$. On this basis, and taking into account pollutant concentrations, emission factors of $3.33 \cdot 10^{-3}$, $2.19 \cdot 10^{-3}$ and $3.66 \cdot 10^{-3} \text{ kg of pollutant Mg OFMSW}^{-1}$, respectively, for NH_3 , CH_4 and VOC were calculated for the vermicomposting process. To our knowledge, there are no values published on the gaseous emissions from vermicomposting to allow comparison.

Vermicomposting process emissions are clearly lower than those coming from home or industrial composting processes (Colón et al., 2012).

3.4 Environmental and social remarks

From an environmental point of view, the immediate advantage of implementing some form of alternative self-managing process for OFMSW is the reduction in the need for waste collection and transport, thereby reducing fuel consumption, gaseous emissions and noise disturbance. Scaling up the values obtained in this work on the capacity of the home composter and the vermicomposter and relating them to a three-member family (Vázquez and Sánchez, 2005), the quantities of waste that could be diverted from the conventional collection and treatment system are presented in Table 4 along with the sizes of the composting bins needed. The fraction of OFMSW that cannot be vermicomposted or that is not recommended for home composting (mainly fish and meat leftovers) should be treated by the municipal waste management system. Waste generation can vary significantly from one family to another according to their lifestyles. Andersen et al. (2011), analysed data from different researchers and reported values of organic household waste fed to a home composter varying from 1 to 53 kg per week for a single family.

At present, Life Cycle Assessment studies of municipal waste management systems are based on their own data and/or literature data from industrial treatment installations and related transport. The results presented in this work can complement the inventory data used in these LCA studies by introducing real data from the most common waste self-management alternatives (home composting and vermicomposting).

The overall results of this work regarding treatment capacity, gaseous emissions and final compost quality should be used in the decision-making process for waste-management systems implementation.

4. Conclusions

A good quality compost product has been obtained from OFMSW for both composting and vermicomposting on a small scale. According to the results obtained, these products are similar to or better than industrial compost. The optimum treatment capacity of the equipment used has been estimated to be 50 g of OFMSW L composter⁻¹ week⁻¹ for a vermicomposter and 16 g of OFMSW L composter⁻¹ week⁻¹ for a home composter.

No odours were detected in the vicinity of the vermicomposter, and only a few episodes of bad odours were observed in the case of home composting when properly managed. NH₃, CH₄ and N₂O emissions from the vermicomposter were three orders of magnitude lower than those emissions from home composting.

Home composting and vermicomposting can be considered suitable alternatives to divert a portion of the OFMSW from the traditional waste management system.

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Tables

Table 1. Characteristics of the waste fed to the home composter and the vermicomposter.

Properties	Home composter	Vermicomposter
Moisture (% , wb*)	75 ± 2	78 ± 4
Organic matter (% , db*)	77 ± 1	95 ± 2
pH (extract 1:5 w:v)	5.9 ± 0.3	7.1
Electrical conductivity (extract 1:5 w:v) (mS cm ⁻¹)	1.9 ± 0.2	1.30
N-Kjeldahl (% , db)	1.6 ± 0.1	2.5
Dynamic Respiration Index (mg O ₂ g ⁻¹ OM h ⁻¹)	3.5 ± 0.9	3.9 ± 0.1

* db: dry basis; wb: wet basis

Table 2. Characterisation of the final products of the two treatment processes. Compost quality standards are also reported for reference.

Properties	Compost		Compost quality standards
	Compost	Vermicast	
Moisture (% , wb)	50.3	76.9	30–40 ^a
Organic matter (% , db)	75.0	55.3	>35 ^a
pH (extract 1:5 w:v)	8.97	7.88	6.5–8 ^b
Electrical conductivity (extract 1:5 w:v) (mS cm ⁻¹)	1.72	4.90	≤6 ^b
N-Kjeldahl (% , db)	1.66	2.04	≥2 ^b
Dynamic Respiration Index (mg O ₂ g ⁻¹ OM h ⁻¹)	0.43	0.89	0.5–1.5 ^c
<i>Salmonella</i> (presence/absence in 25g)	Absence	Absence	Absence ^a
<i>Escherichia coli</i> (CFU/g)	<10	<10	<10 ^a
Zn (mg kg ⁻¹ , db)	194	123.7	200–1000 ^a
Cu (mg kg ⁻¹ , db)	50	40.5	70–400 ^a
Ni (mg kg ⁻¹ , db)	9.0	15.9	25–100 ^a
Cr (mg kg ⁻¹ , db)	13	17.0	70–300 ^a
Pb (mg kg ⁻¹ , db)	26	21.8	45–200 ^a
Cd (mg kg ⁻¹ , db)	0.2	0.3	0.7–3 ^a

wb: wet basis; db: dry basis; w: weight; v: volume; OM: organic matter

^a Regulation proposal for organic fertilisers in Spain (Real Decreto 824/2005)

^b Regulation proposal for municipal solid waste compost in Spain (Giró, 1994; Giró, 2001).

^c Range for stable compost according to California Compost Quality Council (2001).

Table 3. Maximum, minimum and average concentrations (including standard deviation) of the pollutants studied in the gaseous emissions from home composting and vermicomposting and emission factors per Mg OFMSW.

Pollutant	Home composting			Vermicomposting				
	Concentration			Emission	Concentration			Emission
	(ppm _v)			(kg Mg OFMSW ⁻¹)	(ppm _v)			(kg Mg OFMSW ⁻¹)
	max.	min.	aver.		max.	min.	aver.	
NH ₃	17	1.0	6±3	1.3	5.0	3.0	4±1	3.33·10 ⁻³
CH ₄	7.89	1.75	4±1	1.35	3.9	2.0	3.0±0.7	2.19·10 ⁻³
N ₂ O	3.16	0.30	1.3±0.9	1.16	-	-	-	-
VOC	-	-	-	-	31	0	13±13	3.66·10 ⁻³

Table 4. Quantities of OFMSW diverted from the conventional collection and treatment system using home composting and vermicomposting.

	Vermicomposter	Home composter
Week capacity (kg OFMSW/L)	0.050	0.016
Annual capacity (kg OFMSW/L)	2.60	0.83
Needs for a 3-member family ^a (L)	84	264

^a assuming a generation of 200 g of the OFMSW per person per day (excluding meat and fish leftovers)

List of Figures

Figure 1. Experimental set-up: a) home composter; b) vermicomposter.

Figure 2. Temperature evolution during home composting: dotted line: ambient temperature; solid line: home composter temperature (as an average of the values obtained for the three composters).

Figure 3. Transmission Electron Microscopy image of the microstructure of compost and vermicast. (a) Vermicast and (b) Home compost.

Figure 1.



Figure 2.

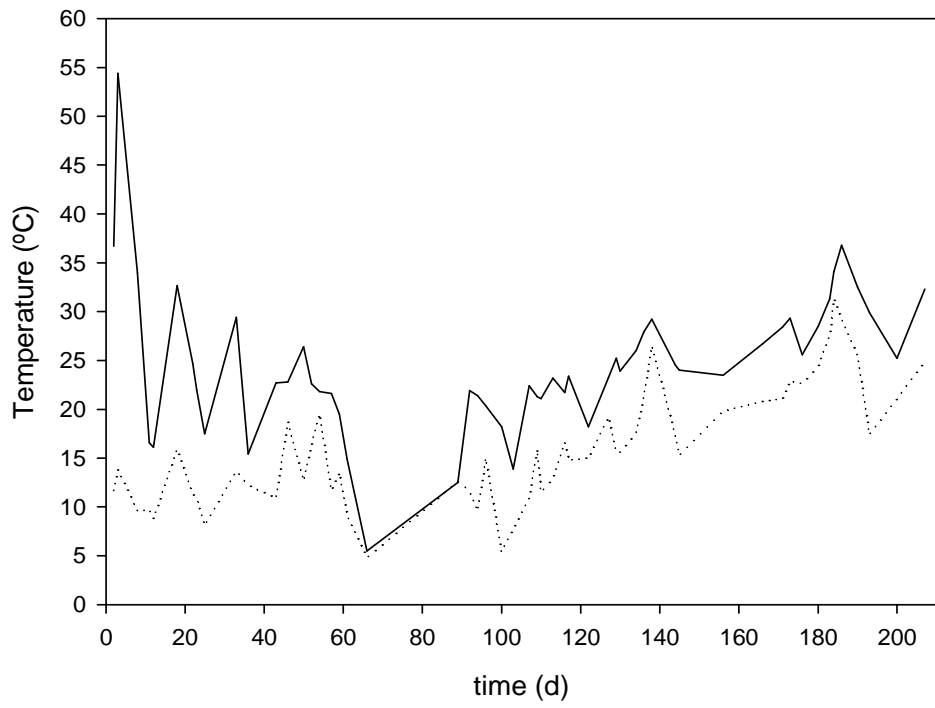
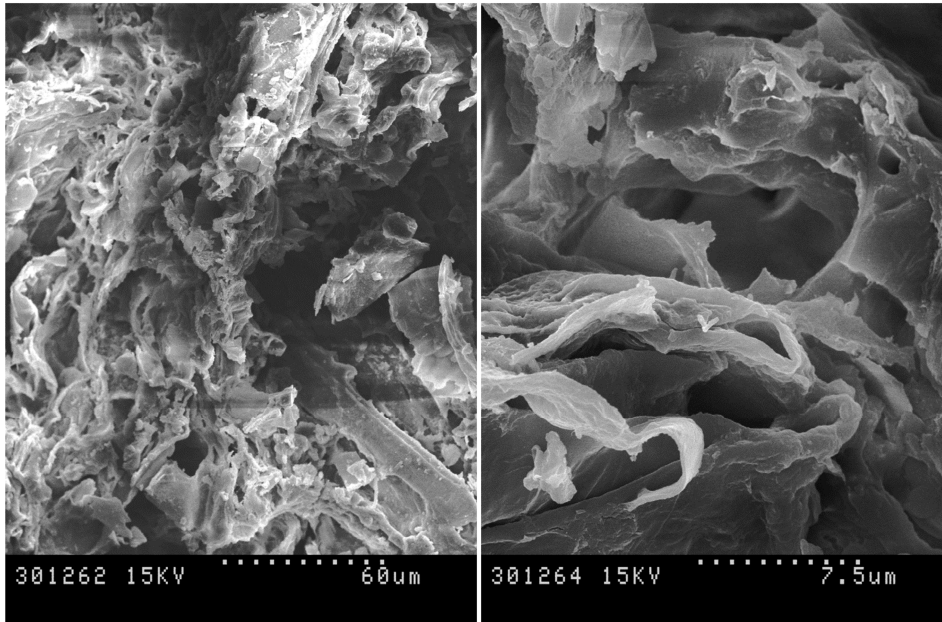


Figure 3.

a)



b)

