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Effect of Feeding Regime on Composting in Bins

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ABSTRACT
Composting in bins is one of the most practical home composting methods. There is currently a need for greater information to improve the management of the composting process and to create home composting programs, which ensure sustainable production of high quality compost. This study investigates how two aspects of the bin feeding regime—the feeding frequency and the amount of waste applied at each feed—influence the process's evolution and the quality of the compost. Compost bins were assayed after introducing the same amount of kitchen and garden waste according to three different frequencies: in a single batch, weekly, or every 3 weeks. A fourth treatment was applied to calculate the potential waste reduction achieved by the composting process, filling the bins to the brim on a weekly basis. Temperature, mass, and volume changes; the microbial diversity (by Biolog); and gas emissions (CO_2, CH_4, N_2O, and NH_3) were all determined during the process. At the end of the experiment, all of the composts were weighed and characterized. Results show that the main differences were very dependent on the quantity of waste provided. Large amounts of waste were added increasing the compost's temperature and maturity during the process, while slightly affecting the salinity and phytotoxicity of the final compost but without any clear effects on microbial diversity and gas emission. Therefore, from a technical point of view, the shared use of compost bins among several households (community composting) is preferable to individual use.

Introduction

The foremost priority of the European Union's waste policy is to prevent the production of waste (Directive 2008/98/EC). To reduce the disposal of biowaste in landfills and to comply with the EU Landfill Directive 1999/31/EC the Thematic Strategy on the Prevention and Recycling of Waste (European Commission 2005) proposed the modification of specific biowaste legislation stimulating preventive actions at all geographical scales, including at a decentralized level. The first step in this process was the preparation of the Green Paper on the management of biowaste (European Commission 2008). Among many other features, the Green Paper encourages home and community composting as sustainable systems for in situ management of organic fraction of municipal solid waste (OFMSW). Home composting has been recognized as an achievable means of reducing the costs of selective collection, transport, and infrastructure (Adhikari et al. 2010; Jasim and Smith 2003; Vazquez et al. 2015) that can provide several environmental benefits (Andersen et al. 2010; Chan, Sinha, and Wang 2011; Hogg et al. 2007; Martínez-Blanco et al. 2010).

Composting in bins is one of the most common methods of biowaste recycling at a home, with an individual bin per household, or community scale, sharing one or more bins between multiple households. Most of the studies about home composting focused on the evaluation of experiences and programs (Adhikari, Trémier, and Barrington. 2012a; Curtis 2009; Papadopoulos et al. 2009; Preston, Cade-Menun, and Sayer 1998; Schwalb et al. 2011), some of these in tropical or developing countries (Benjawan et al. 2014; Faverial and Sierra, 2014; Moqsud, Bushra, and Rahman 2011); others assessed the amount of waste diverted from collection and centralized management (Adhikari et al. 2010; Gale 1990; McKay and Buc 2004; Smith and Jasim 2009) or the social (Edgerton, MsKechnie, and Dunleavy 2008; Tucker and Fletcher 2000) and environmental implications (Barrena et al. 2014; Colón et al. 2010; Chan, Sinha, and Wang 2011; Martinez-Blanco et al. 2010). Some studies evaluated

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the characteristics and quality of community and domestic compost (Evans and Tan 1998; Tàtano et al. 2015; Vázquez, Sam, and Soto 2015) or its agricultural performance (Alexander 2009; Jasim and Smith 2003; Stoichkova and Slavov 2008). Composting users and promoters must be instructed in the practice's operational aspects to ensure proper management at a household or community scale. For example, technical aspects of bin handling were addressed by comparing turning (Alexander 2007; Gethaun et al. 2012; Illmer and Schinner 1997) or composter bin models (Adhikari et al. 2012a; Alexander 2007; Bench et al. 2005; Karnchanawong and Suriyanon 2011; Kumar, Jayaram and Somashekar 2009), and other studies performed an environmental assessment of different bin configurations (Adhikari et al. 2012b; Andersen et al. 2012; Ermolaev et al. 2014; McKinkley 2008).

One important feature of composting in closed bins that needs to be clarified is the effect of the feeding regime on the evolution of the process and the quality of the final compost. In community composting, where different bins are shared between several families, the frequency and the size of feed can vary in function of the capacity and number of bins available per household (Adhikari et al. 2010). Information about the optimal feeding regime is fundamental for planning future decentralized composting programs and determining how many bins are needed, and of what size to serve a given area or population.

In a typical small-scale composting facility, the so-called "bin feeding regime" can be defined by different combinations of the frequency and size of fresh waste additions. This article studied two aspects of the feeding regime: the frequency and amount of waste applied at each feed. The smaller scale and size of waste additions are the main differences between decentralized (home or community) and industrial composting, and need to be taken into account when experimentally studying the factors that can influence both processes (Barrena et al. 2014; Illmer and Schinner 1997). The periodicity of bin waste addition is influenced by seasonal and geographical variations in waste production levels and by the composting trends and consumption habits of each household. Home composting facilities are typically fed with small amounts of waste at high frequencies.

The available literature describes the effects of waste addition size, but does not address feed frequency. When investigating small-scale composting in windrows, rotary drums or bins fed with a single, large, initial waste addition or with smaller weekly ones, Adhikari, Trémier, and Barrington (2012b) observed that larger additions can promote higher temperatures and a faster decomposition process. This trend of producing higher temperatures with large waste additions was also observed by McKinley (2008), but no significant differences in weight reduction were observed between small or large waste additions. A study of composting catering waste in bins (Rudé and Torres 2011) concluded that the size of each waste addition had less influence on composting temperature than the bulking agent ratio, but more influence than the turning frequency. The final results of that study showed that the size of raw waste additions was one of the most influential factors on final compost maturity and quality, and also on weight reduction during composting, with smaller additions producing less reduction.

Home and community composting have the potential to reduce indirect greenhouse gas emissions with minimal collection, transportation, and mechanical handling requirements compared to other organic waste management options, such as land-fill, incineration, anaerobic digestion, or composting in centralized facilities (Amlinger, Peyr, and Cuhls 2008; Andersen et al. 2012; Chan, Sinha, and Wang 2011; Martinez-Blanco et al. 2010). Gas emissions produced by composting in bins have previously been addressed in home composting studies involving a variety of waste types, such as garden and food waste, and with very different approaches and conclusions (Adihkari et al. 2013; Amlinger, Peyr, and Cuhls 2008; Andersen et al. 2010; Chan, Sinha, and Wang 2011; Colón et al. 2010; Ermolaev et al. 2014; Jasim and Smith 2003; McKinley 2008). The various studies did reach one common conclusion, however; the higher the decomposition activity during the composting process, the greater the emission of gases. Large additions of waste maximize microbial activity, with the bin reaching higher temperatures and thus increasing gas emissions (Andersen et al. 2010). Frequent small additions increase the frequency of turning operations associated with bin feeding, increasing CO_2 (Ermolaev et al. 2014) and decreasing CH_4 emissions (Amlinger, Peyr, and Cuhls 2008).

The aim of this work is to analyze the effects of feeding regime frequency and size on the composting process and the final quality in compost bins.

Materials and Methods

Experimental Setup

The trial was carried out from March to December at an experimental site controlled by the Public University of Navarre, Pamplona, in northern Spain. The study used sixteen 320-liter, dark-green, plastic compost bins (Komp 320 Container Trading WFW, Austria).

All bins were filled with the same mixture of vegetal food and garden waste. The garden waste comprised chipped pruning residues from winter wood as a bulking agent to favor aeration and prevent leachate formation (with a food waste/pruning residue fresh volume ratio of 1:0.7). The vegetal food was composed of fresh fruit and vegetable scraps, sourced from local street markets. Although the composition of the food waste was heterogeneous, its variability simulates that of usual kitchen waste in terms of seasonal variations and different household trends. The initial mixture had a moisture content of 65%–70% and an average C/N weight ratio of 17:1. Electrical conductivity, however, presented a higher initial variability, ranging from 430 to 3200 μS/cm (average of 1220 μS/cm). The initial mixture's density ranged from 180 to 330 kg/m^3 (average, 220 kg/m^3) and the pH from 6.0 to 7.4 (average, 6.8).

The whole experiment lasted 30 weeks, including: a 7-week preliminary phase, 6 weeks feeding the bin according to treatment regimes, and a 17-week maturation phase.

The preliminary phase was common to all treatments and carried out to guarantee a minimum initial amount of waste and thus ensure the correct initiation of the composting starter. During this preliminary phase, all bins were fed in the same way, with 30 (±5) kg of organic waste in just a single initial addition. The preliminary phase was considered to have finished 7 weeks later, when the volume of material in the bins had halved. This condition was reached practically simultaneously in all of the bins, irrespective of their temperature.

During the second phase bins were fed according to the corresponding treatment, following four different feeding regimes over a 6-week period (table 1). For the first three treatments, 103 Kg of organic material was added during the second phase. The bins of the "BATCH" treatment were filled with a single waste addition (103 Kg). For the "THREE" treatment, the total amount of 103 Kg of fresh waste was provided to each bin in three separate additions of 34 Kg every 3 weeks. In a third treatment called "WEEK," the 103 kg total was distributed over seven weekly additions of 15 kg each. For the fourth treatment, "MAX," the bins were filled to their maximum capacity on a weekly basis. Each addition in this treatment had a different weight: the first feed was 103 kg (as "BATCH") and the following feeds decreased from 26 to 5 kg depending on the headspace encountered in the bins 1 week after the previous feed (table 1). Four replicates of each treatment were performed following a randomized block experimental design; one bin corresponded to one experimental unit.

Table 1. Organic waste added to bins under different feeding regimes.

	BATCH	THREE	WEEK	MAX
Preliminary phase:				
Mass of addition (kg)	30	30	30	30
No. of additions	1	1	1	1
Second phase:				
Mass of addition (kg)	103	34	15	25 (5–103)
Cumulative mass of additions (kg)	103	103	103	175
No. of additions	1	3	7	7

After the feeding period, the maturation stage was performed equally across all treatments, without any further additions. The maturation phase took 17 weeks. During this phase, bin handling was reduced to a minimum (only weekly turning and watering). The composting process was considered to be complete when each bin reached Rottegrade maturity index IV, determined as described below. At the end of the maturation phase, the trial was ended and the composts sampled and analyzed.

The compost was turned and mixed 16 times throughout the trial using a hand-held spiral aerator tool, with more frequent turning in the early stages to ensure aerobic conditions and to accelerate decomposition (Alexander 2007; Getahun et al. 2012; Illmer and Schinner 1997). The compost was watered on three occasions when observed to be too dry (figure 1). For operational reasons, watering was performed simultaneously on all treatments, but with different volumes according to needs (20–30 L). All four replica bins receiving the same treatment demonstrated similar moisture levels and received equal volumes of water. Moisture content during composting was monitored qualitatively twice a week using the "fist test." This involves squeezing a compost

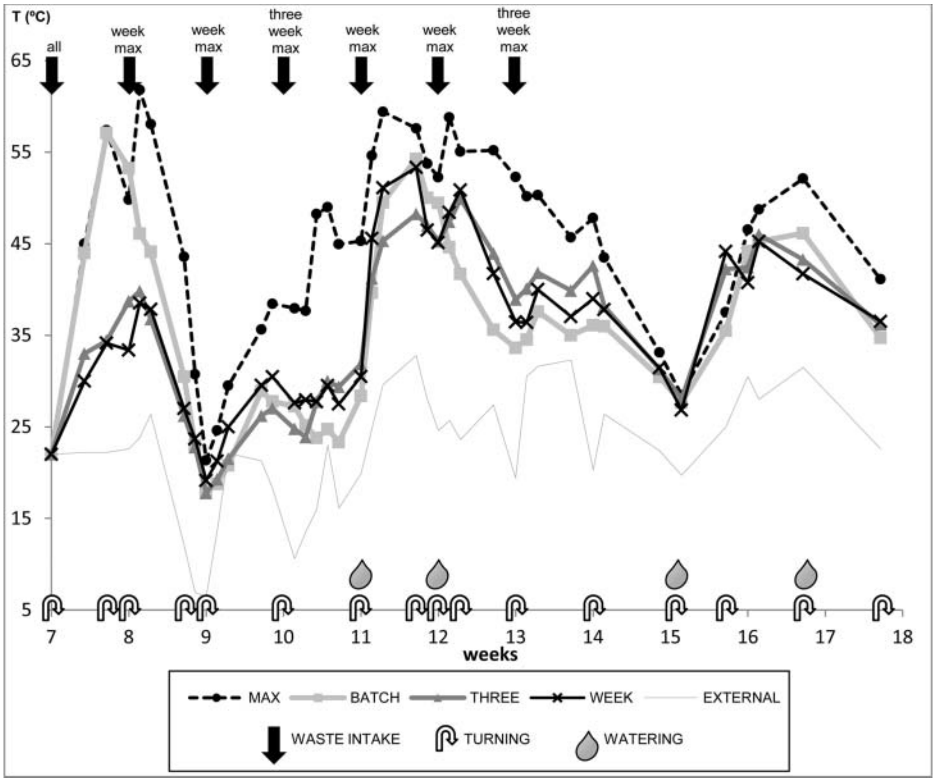

Figure 1. Temperature development during the first 18 weeks of composting in bins treated with different feeding regimes.

sample in the fist; if water emerges from the fist, then the sample is too wet. The moisture content is suitable (approximately 50%–60%) if the pressed sample does not release water but remains compact; if it crumbles apart when released, it is too dry (FCQAO 1994). Dry matter and moisture levels of the final compost were determined (prior to sieving) after drying the samples to a constant mass at 70°C (TMECC 2002).

Evolution of the Composting Process

The temperature inside each bin was measured using a digital, stem thermometer (HI 93510N, Hanna Instruments, Italy) placed in the middle of each bin's contents. The reported value was the average of four measurements in different places inside the bin. The number of thermophilic days (NTD) was recalculated to take into account the days that the temperature of the compost was higher than 45°C. The thermophilic heath sum (THS) was calculated as the sum of the daily differences between the temperature reached by the compost and the thermophilic threshold temperature (45°C).

Compost volume variations were determined by measuring the height reached by the compost inside the bin. Weight losses were calculated by taking the final compost weight and expressing it as a percentage of the total sum of waste additions (Breitenbeck and Schellinger 2004). The volume-loss ratio was calculated in the same way.

Gaseous emissions of CO_2, CH_4, NH_3, and N_2O were measured twice during weeks 10 and 13 of the trial. During the first measurement, the emissions were monitored for 96 h following the last waste addition to the MAX, THREE, and WEEK bins. For the second measurement, emissions were monitored during the first 46 h after feeding. Gas emissions were measured following the method described by Menéndez et al. (2009) using an open chamber technique. Concentrations of gases were measured at the air inlet and outlet of the chamber using a photoacoustic infrared gas analyzer (Model 1302 Multi-Gas Monitor; Brüel and Kjær™, Denmark) for approximately 5 min, after having reached the steady-state value. Fluxes were calculated from the concentration differences between inlet and outlet air, the air flow rate through the chamber, and the surface area covered by the chamber. Cumulative emissions during the sampling period were estimated by averaging the rate of loss between two successive determinations, multiplying that average rate by the length of time between the measurements, and then adding that amount to the previous cumulative total. Reported results are presented as average fluxes during each sampling period.

Phenotypic variability of the microbial community during the composting process was studied by comparing three indexes derived from a Biolog analysis of compost at the beginning of the maturation phase (Frąc, Oszust, and Liepic 2012). The Biolog Ecoplate^{TM} (Biolog^{TM}, USA) contains 30 wells with different carbon sources and one control well with no carbon source. The rate of utilization of different substrates by different groups of microorganisms varies; thus, one can observe high variability in the rate and intensity of color development in tetrazolium violet redox dye depending on the metabolic profile of the microbial community (Garland and Mills 1991). The number of used substrates (NUS) was counted for each plate. Overall, metabolic activity on a plate was expressed as the average well color development (AWCD), an index correlated with the optical density of each well (Riddech, Klammer, and Insam 2002). The Shannon index (H) was used as a measure of diversity of the extent of utilization of particular substrates (Stefanowicz 2006). All indexes measured at 24, 48, and 72 h after sample preparation were reported.

Quality of Final Compost

Final samples taken at the end of the composting process (week 30) were analyzed in order to estimate compost stability and maturity using the self-heating test in a 1.5-L Dewar flask (Brinton, Evans, and Droffner 1995) and a commercial maturity test (Solvita^{TM}, Woods End Research Laboratory, USA), which estimates the microbial activity by scoring the compost against an index based on CO_2 and NH_3 production (Changa et al. 2003).

To determine any possible phytotoxic effects of the compost, a germination bioassay was conducted following the method described by Zucconi et al. (1981). In this bioassay, 12 cress seeds cv. Alenois (*Lepidium sativum* L.) and 12 lettuce seeds cv. Solana (*Lactuca sativa* L.) were placed in Petri dishes with different dilutions of compost water extract to observe whether different treatments affected germination.

The compost was sieved through a 16-mm mesh and then analyzed. The density of the compost was measured (FCQAO 1994). Electrical conductivity and pH (TMECC 2002) were determined in aqueous extracts of compost/water at a 1:5 volume ratio. Granulometric distribution was determined by sifting through different sieves with 16-, 8-, 4-, and 2-mm mesh sizes (Ansorena 1994). Finally, the coefficient of uniformity described by Terzaghi, Peck, and Gholamreza (1996) was calculated using the equation:

$$CU = D_{60}/\ D_{10},$$

in which D_{60} is the mesh size at which 60% passes, and D_{10} is the mesh size at which 10% passes.

Levels of total N, total C, and organic C were determined using an elemental analyzer (LECO Truspec CN, LECO Corporation, USA). P, K, S, Ca, Mg, B, Mn, Na, Fe, Cu, Cd, Cr, Pb, Ni, and Zn levels in final composts were determined by ICP-OES (ICAP 6500 DUO, Thermo Scientific, USA) following microwave digestion with HNO_3 and H_2O_2 (UltraCLAVE, Milestone Srl, Italy).

To characterize the organic matter in the compost, total humic extract and humic acids content were determined with the sequential fractionation procedure described by Dabin (1971) and Duchaufour (1977). Total humic extract was derived from extractions with $Na_4P_2O_7$ and NaOH. The humic acids fraction was precipitated from the total humic extract using HCl (pH 1–2). The organic carbon content of the different fractions was determined by dichromate oxidation and Mohr salt titration following the Walkley–Black method (Walkley and Black 1934). The weight of each fraction was calculated assuming a content of 58% of C and that 77% of the organic C was oxidized (Nelson and Sommers 1982).

Statistics

Final data were analyzed with one-way variance analysis. The Duncan test for separation of media was conducted for gaseous emission results ($p < 0.05$), while the Student–Newman–Keuls test was conducted ($p < 0.05$) for the remaining results. Statistical tests were performed using SPSS 19.0 (IBM, USA) statistical software for Windows.

Results and Discussion

Evolution of the Composting Process

In general, differences between treatments concern the evolution of the composting process more than the final quality.

Composting proceeded satisfactorily in all bins. There were no issues like bad smells or rodents during the trial. The presence of a few fruit flies (*Drosophila melanogaster* Meigen) and some spider mites (*Tetranychus* sp.) was observed after the first waste additions, but they were no longer present after 1 week. During the preliminary phase, not a single bin reached thermophilic temperatures (>45°C), probably due to the low amount of waste inside. During the second phase, the temperature inside the bins reached the thermophilic threshold (45°C) for all treatments and it was greatly influenced by the external temperature and the compost's moisture content (figure 1). Important temperature differences were observed among the different feeding regimes. Treatments with larger waste additions (MAX and BATCH) clearly presented a greater temperature development than other treatments, and also experienced the highest number of thermophilic days and the largest thermophilic heath sum (table 2). All treatments present temperature rise after the supply of new waste. THREE and WEEK bins were filled with smaller waste additions than BATCH, but more frequently. After 9 weeks of composting process, beyond an initial increase, temperature inside BATCH bins decreased to the same level of the other two treatments. Although these three treatments showed no difference for average temperature, BATCH presented a longer thermophilic phase. Therefore, this result suggests that the size of waste addition could influence the composting temperature more than the feed frequency, as was described in previous studies (Adhikari, Trémier, and Barrington 2012b; McKinley 2008).

Table 2. Temperature profiles during composting in bins under different feeding regimes.

	BATCH	THREE	WEEK	MAX
Maximum temperature (°C)	57.1 a	49.9 b	53.3 b	61.8 a
Average temperature (°C)	36.5 b	36.0 b	36.1 b	44.8 a
NTD*	13.5 a	4.25 b	2.25 b	17.5 a
THS†	77.5 a	4.9 b	3.9 b	71.4 a

Note. Values in each line followed by the same letter are not significantly different (SNK test, $p \leq 0.05$, $n = 4$).
*Number of thermophilic days (T > 45°C) since last waste addition.
†Thermophilic heat sum: THS = Σ_{day} (T – 45°C) since last waste addition.

Table 3. Weight and volume loss ratios under different feeding regimes.

	BATCH	THREE	WEEK	MAX
Weight loss ratio* (%)	66.0 a	66.4 a	65.8 a	70.1 b
Volume loss ratio† (%)	65.4 a	57.6 a	58.9 a	62.4 a

Note. Values in each line followed by the same letter are not significantly different (SNK test, $p \leq 0.05$, $n = 4$).
*Weight loss ratio = 100 × [1 – final weight/(preliminary phase waste addition + total waste addition)].
†Volume loss ratio = 100 × [1 – final volume/(initial volume + sum of volume increments due to waste additions)].

Compost moisture content had an influence on the temperature during the composting process, especially during the later stages of monitoring when the external temperature was higher. It is likely that organic matter degradation slowed due to a lack of moisture interfering with microbial activity. However, the process recovered its activity quickly after watering (figure 1). According to McKinley (2008), this effect was mainly observed for treatments with larger feed sizes (BATCH and MAX) in which higher temperatures promoted higher water loss due to evaporation. In fact, greater amounts of water were needed to ensure optimal moisture level in both BATCH and MAX treatments, as concluded from "fist test" results and qualitative observation of the compost.

The weight reduction during the process was slightly, but significantly, higher for the MAX treatment (table 3) in comparison with the other treatments, as it reached higher temperatures during composting (table 2). This influence of temperature on the decomposition rate during composting has been known for some time (Kuter, Hoitink, and Rossmann 1985; Waksman, Cordon, and Hulpoi 1939; Zhang and Matsuto 2010). All of the other treatments did not present any significant differences in weight loss ratios. Volume reductions ranged between 57.6 and 65.4%, with no significant differences observed among treatments. In general, the volume was observed to decrease by more than 40% during the first month after the last feed of new waste.

The maximum potential of a 320-L bin, under the specific experimental conditions of this trial, was determined from the MAX treatment in which a total of 205 kg of organic waste was added over 91 days of

Table 4. Average emission levels measured twice during composting in bins under different feeding regimes.

	BATCH	THREE	WEEK	MAX
Week 10:				
CO_2 (mg of C m^{-2} h^{-1})	719 d	1948 b	9292 a	1417 c
CH_4 (mg of C m^{-2} h^{-1})	4.5 a	3.5 a	3.9 a	1.7 a
N_2O (mg of N m^{-2} h^{-1})	0.1 c	0.7 b	7.2 a	0.9 b
NH_3 (mg of N m^{-2} h^{-1})	0.6 a	0.7 a	0.4 a	0.5 a
Week 13:				
CO_2 (mg of C m^{-2} h^{-1})	3652 c	6000 a	4261 b	6435 a
CH_4 (mg of C m^{-2} h^{-1})	11.8 a	10.8 a	10.6 a	8.8 a
N_2O (mg of N m^{-2} h^{-1})	0.2 c	1.6 b	2.3 b	11.0 a
NH_3 (mg of N m^{-2} h^{-1})	2.5 a	2.4 a	2.3 a	2.7 a

Note. Values in each line followed by the same letter are not significantly different (Duncan test, $p \leq 0.05$, $n = 4$).

active handling followed by 120 days of maturation (table 3).

Gas emissions were higher in week 13 than week 10 (table 4). This difference was probably due to low moisture content in week 10 before any watering had been performed. After week 10, bins were watered twice before the next measurement in week 13, thus increasing the moisture level. The BATCH treatment presented lower CO_2 (and N_2O) emissions than the other treatments. In contrast to the rest of the treatments, BATCH bins were not filled from week 7. This result could indicate that new waste feed increases emissions more than the prior amount present in the bins, as was observed by McKinley (2008). With regard to methane, no significant differences were observed between treatments. In any case, the majority of carbon emissions were in the form of CO_2, and methane emissions did not exceed 0.62% (range 0.04%–0.62%, mean 0.23%) of total carbon gas emissions (BATCH treatment). These percentages are similar to those found by Chan, Sinha, and Wang (2011) and Ermolaev et al. (2014) for composting in bins. In summary, these results show that the composting process was predominantly aerobic. The increase of CH_4 emissions during the experimental period was probably due to the high microbial activity (higher at the second measurement) during the composting process. This would have consumed interstitial oxygen, thereby establishing anaerobic conditions for methane production (Beck-Friis et al. 2000). Nitrogen gas emissions were very low for both NH_3 and N_2O. The highest peak value of N_2O emitted after a waste addition was 11 mg of nitrogen m^{-2} h^{-1} for the MAX treatment (range 0.1–11.0, mean 3.0); this is very low, but similar to that described by Chan et al. (2011). Ammonia emissions were also very low and showed no significant differences between treatments. Notwithstanding this lack of any significant differences between treatments, there was a trend towards higher values being associated with larger feed sizes (BATCH > THREE > WEEK), which is consistent with other authors' findings (Adhikari et al. 2013; Andersen et al. 2010). Finally, it should to be taken into consideration that these measurements were only snapshots of gas emissions at two instances during the experiment and may not represent the overall emissions during the whole composting process.

Table 5. Stability and maturity parameters of final composts under different feeding regimes.

	BATCH	THREE	WEEK	MAX
Solvita® Index results (range, $n = 4$)	4–6	3–5	4–5	4–7
Dewar self-heating test:				
Rottegrade	IV	IV	IV	V
Maximum difference $T_{compost} - T_{extern}$ (°C)	14.4	17.6	13.5	8.4
Days with $T_{compost} - T_{extern} > 10$°C	5	9	4	0

Maturity and Quality of Final Compost

We have already seen that larger waste additions increased the observed temperature during composting as a result of higher microbial activity. Consequently, with a higher level of microbial activity, compost maturity was influenced as described previously (de Bertoldi, Vallini, and Pera 1983; Liang, Das, and McClendon 2003; Nakasaki, Shoda, and Kubota 1985; Trémier et al. 2005).

Results of Dewar tests showed higher stability of compost of the MAX treatment (table 5). No clear trend was observed in the other treatments. The Solvita™ index was also higher for the MAX treatment, where the feed addition size was greater. These results suggest that the larger fresh waste addition speeded up the composting process, probably due to higher microbial activity, as described previously by Adhikari, Trémier, and Barrington (2012b). Rudé and Torres (2011) observed that, while the total duration of the composting process did not depend on the bin feeding regime, the compost bins that received larger waste additions required more time without feeding (maturation phase) to reach the same level of stability. The period without feeding was longer for the BATCH treatment because the last waste addition was much earlier than in other treatments. However, the BATCH regime did not lead to greater stability or maturity than MAX. Contrary to the conclusions of Rudé and

Table 6. Characteristics of final compost in bins under different feeding regimes.

	BATCH	THREE	WEEK	MAX
pH	8.8 a	8.6 a	8.7 a	8.8 a
Conductivity (μS/cm)	1370 b	1550 a	1640 a	1280 b
Density (kg/m^3)	285 a	279 a	305 a	324 a
Dry matter* (%)	49 a	57 a	57 a	62 a
Granulometric uniformity†	5.7 a	6.7 a	6.5 a	7.6 a
Total N (%w/w)	2.7 a	2.6 a	2.7 a	2.7 a
Total C (%w/w)	39.4 a	40.1 a	38.9 a	38.9 a
Organic C (%w/w)	38.2 a	38.4 a	37.8 a	37.3 a
Total humic extract (%w/w)	14.6 a	14.7 a	14.4 a	14.3 a
Humic acids (%w/w)	7.7 a	7.8 a	7.6 a	7.5 a
C:N ratio	14.5 a	16.7 a	14.6 a	13.8 a
P (%w/w)	0.46 a	0.43 a	0.49 a	0.44 a
K (%w/w)	1.43 a	1.41 a	1.56 a	1.55 a
Ca (%w/w)	2.6 a	2.7 a	2.9 a	2.8 a
Mg (%w/w)	0.28 a	0.27 a	0.30 a	0.31 a
S (%w/w)	0.27 a	0.25 a	0.29 a	0.28 a
Na (%w/w)	0.30 a	0.33 a	0.34 a	0.29 a
Fe (mg/kg ds)	1243 a	1085 a	1438 a	1166 a
Cu (mg/kg ds)	19 a	24 a	29 a	26 a
Mn (mg/kg ds)	64 a	53 a	65 a	60 a
B (mg/kg ds)	30 a	33 a	34 a	33 a
Zn (mg/kg ds)	101 a	84 a	107 a	74 a
Cd (mg/kg ds)	<0.5 a	<0.5 a	<0.5 a	<0.5 a
Cr (mg/kg ds)	4.7 a	2.4 a	2.2 a	2.9 a
Pb (mg/kg ds)	6.6 a	5.3 a	6.4 a	4.3 a
Ni (mg/kg ds)	4.8 a	3.7 a	4.7 a	3.8 a

Note. Values in each line followed by the same letter are not significantly different (SNK test, $p \leq 0.05$, $n = 4$).
*Before sieving.
†Coefficient of uniformity = D_{60}/D_{10}.

Torres' study, the results obtained here suggest that compost maturity was influenced by feed size regardless of the length of the maturation period.

In terms of the quality of the final compost, the quality parameters were scarcely affected by the differences in feeding regimes (table 6). No significant differences were observed for the compost's main physical parameters (dry matter, density, pH, and coefficient of granulometric distribution uniformity). The pH of composts ranged from 8.6–8.8, dry matter from 49%–62%, and the density from 279–324 kg/m^3, as described for homemade compost in other studies (Preston, Cade-Menun, and Sayer 1998; Smith and Jasim 2009). On the other hand, very slight but significant differences in conductivity were observed between treatments (table 6). The lowest values were recorded for treatments associated with larger waste addition sizes (BATCH and MAX), which reached the highest temperatures during composting. Despite the higher microbial activity in BATCH and MAX treatments, the weight and volume loss ratios (table 3) were no higher than in other treatments, suggesting that solute enrichment did not differ between feeding regimes.

By the same token, C, N, P, K, S, Ca, Mg, Mn, B, Na, Fe, Cu, Cd, Cr, Pb, Ni, and Zn concentrations also presented no significant differences between treatments. The study carried out by Rudé and Torres (2011) concluded that larger feed additions help to preserve carbon and nitrogen from initial materials in the final compost and result in a lower C/N ratio. When greater microbial activity and a higher level of compost maturity were observed, a reduction of C/N ratio and an increase in organic matter humification (total humic extract and humic acids) could be expected in association. In contrast to those expectations, in this study no significant differences were observed for total N and C content or for organic matter fractions (organic C, total humic extract, and humic acids) (table 6).

In relation to the germination bioassay (table 7), it should be noted that the WEEK compost regime presented a higher phytotoxicity than the other treatments. However, on *Lactuca* s., only the WEEK treatment showed phytotoxicity in all four replicas. In addition, a 50% dilution of compost extract from the WEEK treatment showed phytotoxic activity on *Lepidium* s. seeds. It is likely that the lower temperatures in the WEEK treatment during composting and the lower number of days under thermophilic conditions after the final feed

Table 7. Index of germination (IG_e) results by bioassay under different feeding regimes (phytotoxic when $IG_e < 60$).

	BATCH	THREE	WEEK	MAX
Lepidium sativum:				
Without dilution	**1**	**35**	**12**	**29**
50% dilution	73	85	**30**	84
25% dilution	*124*	152	93	*133*
Lactuca sativa:				
Without dilution	61	64	**40**	67
50% dilution	*79*	*94*	81	67
25% dilution	*121*	*148*	*180*	*127*

Note. In bold letters, phytotoxic in all replicas. In italics, no phytotoxicity in any of the replicas.

Table 8. Phenotypic variability of the microbial community during composting under different feeding regimes (Biolog Ecoplate™ test results).

	BATCH	THREE	WEEK	MAX
Average well color development:				
24 h	0.53 a	0.27 a	0.46 a	0.48 a
48 h	1.10 a	0.74 a	0.94 a	0.92 a
72 h	1.36 a	0.97 a	1.16 a	1.18 a
Number of used substrates:				
24 h	24.6 a	22.0 a	25.0 a	24.0 a
48 h	28.3 a	26.6 a	26.6 a	25.5 a
72 h	29.3 a	27.0 a	28.0 a	29.0 a
Sharon index (H):				
24 h	2.69 a	2.55 a	2.76 a	2.77 a
48 h	3.05 a	3.05 a	3.00 a	3.09 a
72 h	3.16 a	3.11 a	3.11 a	3.17 a

Note. Values in each line followed by the same letter are not significantly different (SNK test, $p \leq 0.05$, $n = 4$).

were not enough to inactivate any phytotoxic compounds. In all other treatments, in which the greater waste addition size increased microbial activity, the composts produced were less phytotoxic.

No significant differences between treatments were observed for Biolog™ principal indexes (AWCD, NUS, H), which are associated with microbial profiles of carbon source utilization (table 8). These results indicate that feed frequency did not strongly affect the phenotypic diversity of the microbial populations. Nevertheless, as with the measurement of gas emissions, the determination of Biolog™ indexes were only snapshots taken at the beginning of the maturation phase, and the evolution of microbial populations should be studied throughout the entire composting process.

Conclusions

According to the results of this study, different feeding regimes applied to a 320-L composting bin affect both the composting process and, to some degree, the final compost quality. Generally, the main differences between the treatments were related to the quantity provided in each feed than to their frequency. The addition of large amounts of waste increased the temperature during composting and accelerated its maturity. With regards to gas emissions, the process was predominantly aerobic in all of the cases and nitrogen gas emissions were very low. Emissions were influenced more by the size of each single waste addition than by the total feed amount. No differences were observed between treatments in terms of volume and weight reduction rates, final moisture, density, pH, and elemental composition of final composts, nor for the microbial diversity during the composting process. However, the feeding regime can influence slightly the salinity and phytotoxicity of compost. Therefore, with respect to composting bin management, we recommend that larger waste additions are made less frequently. As a practical consequence of these results and considering a process point of view is taken, shared use of composting bins among several households (e.g., in community composting practices) is preferable to individual use (e.g., in typical home composting techniques).

Finally, a 320-L compost bin can completely process 205 kg of kitchen and garden waste in 13 weeks of active handling.

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