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Home composting versus industrial composting. Influence of composting system on compost quality with focus on compost stability

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Abstract

Stability is one of the most important properties of compost obtained from the organic fraction of municipal solid wastes. This property is essential for the application of compost to land to avoid further field degradation and emissions of odours, among others. In this study, a massive characterization of compost samples from both home producers and industrial facilities is presented. Results are analysed in terms of chemical and respiration characterizations, the latter representing the stability of the compost. Results are also analysed in terms of statistical validation. The main conclusion from this work is that home composting, when properly conducted, can achieve excellent levels of stability, whereas industrial compost produced in the studied facilities can also present a high stability, although an important dispersion is found in these composts. The study also highlights the importance of respiration techniques to have a reliable characterization of compost quality, while the chemical characterization does not provide enough information to have a complete picture of a compost sample.

Keywords: home composting; industrial composting; compost quality; respiration; stability.

1. Introduction

Composting is one of the most environmentally friendly technologies for the management of the organic fraction of municipal solid waste (OFMSW) or biowaste, allowing its material valorisation. At industrial level, composting of OFMSW has been extensively studied and the number of treatment facilities implemented has been increasing in last years. Although less studied, home composting has been proposed as an alternative or a complimentary way to manage household OFMSW (Andersen et al., 2013; Martínez-Blanco et al., 2010).

Recently, home and industrial composting have been studied and compared focusing on their environmental impact, mainly energy consumption and environmental burdens (Colón et al., 2012; Martínez-Blanco, 2010; Adhikari et al., 2013). Considering environmental aspects, home composting presents some potential benefits as the avoidance of collection and transportation of biowaste. However, the home composting of the OFMSW also presents some environmental concerns mainly due to the absence of gas treatment systems. In spite of the evident environmental benefits of composting, greenhouse gases (GHG) can be generated and emitted to the atmosphere during the process, thus contributing to global warming (Colón et al., 2012).

Regarding this, the use of compost as an organic amendment can contribute to mitigate GHG emissions. Compost utilization can reduce the need of chemical fertilisers and pesticides (Martínez-Blanco, 2011). Also, it has a positive effect on soil structure that helps to reduce the requirements for water irrigation in periods of drought and to increase the potential of soils to retain moisture (Favoino and Hogg, 2008). Furthermore, one of its highlighted aspects is the potential for sequestration of carbon in soils where compost has been applied (Favoino and Hogg, 2008). For all these purposes, compost produced in home and industrial composting should be a high quality product to guarantee all the benefits of its application, otherwise its use could lead to a higher environmental impact or to reduce agronomic productivity (phytotoxicity).

Thus, the use of compost requires a quality product, stable and free of phytotoxic compounds. The physicochemical characteristics of mature composts have been correlated with the properties of the raw feedstock rather than the process itself (Manios, 2004). In fact, product quality depends both on the original materials and the technology used (Tognetti et al., 2005). For municipal solid waste, heavy metals content is one of the most controversial aspects in compost quality and it has been widely studied. Compost from source separate collected organic fraction of MSW is typically well below the limits of the standards of quality (Smith, 2009). Nevertheless, it strongly depends on the management systems used and, in this regard, door-to-door waste collection systems have been shown as the most appropriate strategy (Colón et al., 2013). Compared with industrial composting, home composting implies a better control of the material treated, reducing impurities.

Compost stability is defined as the extent to which readily biodegradable organic matter has been decomposed (Lasaridi and Stentiford, 1998). Although there is a general agreement about the importance of this parameter, a consensus still has not been reached about which should be the most suitable measurement. Methodologies based on biological assays appear to be more feasible, and aerobic respiration indices have been widely suggested in the literature as a measure of biodegradable organic matter content or stability (Adani et al., 2004; Barrena et al., 2006; de Guardia et al., 2010). For some of them, there are protocols for its use as stability indicators in some European countries as Germany (Federal Government of Germany, 2011), Italy (Favoino, 2006) and England and Gales (Turell, 2009).

The aim of this study is to compare the compost quality of a large number of compost samples from the OFMSW home composting and industrial composting. Physicochemical properties, heavy metals content, nutrients and stability were evaluated in 27 samples from home composting and 25 from industrial composting. Regarding stability, measures of the DRI (dynamic respiration rate) and dynamic AT_4 (cumulative respiration at four days), both parameters used by several authors (Adani et al., 2004, Tremier et al., 2005, Wagland et al., 2009; Ponsá et al., 2010) were determined. A more complete study on stability, analysing

compost and final products from industrial facilitieswas also carried out, taking into account the technology used and the waste treated

2. Material and Methods

2.1 Compost sampling

27 samples from home composting were obtained from 27 different composters, all them located in Spain. Samples from home composting were divided into several categories in accordance to the place where the composter was located. The categories were defined according the use of the composter: individual (Family) or collective (School and Community). Samples from Community category were obtained from composters located in neighbourhoods and canteens. Also, some samples from Family vermicomposters were analyzed and compared with home compost as an alternative for the self-management of biowaste.

25 samples from composting plants, all them located in Spain, treating source separate collected OFMSW were analyzed. Samples came from waste treatment facilities where different technologies were applied. For a detailed study samples from OFMSW were divided in two categories: OF-MSW_I includes only samples from composting in turned windrows, which is one of the common technologies used in the area of study. OF-MSW_II incorporates samples from more technologically complex processes, mostly in-vessel composting systems, but also composting in confined windrows and the combination of anaerobic digestion plus composting. To enrich the discussion, final products from the mechanically separated organic fraction of MSW (OFMS-MSW) and from composting of sewage sludge (SLUDGE) were also analyzed and incorporated to the comparison (10 samples). All the samples were collected from full-scale facilities of Spain.

Analytical methods were carried out on a representative sample (between 2 and 5 kg for home compost and around 10-15 kg for industrial compost) obtained directly in bin composters and in composting facilities. After collection, when it was necessary, samples were ground to 15–20 mm size of particle to reduce the dimension of the original materials and to obtain more

representative samples. Final samples of industrial compost had been already screened in the plants. Samples were frozen and conserved at -18ºC. Before analysis, the samples were thawed at room temperature (25ºC) and time requested should not exceed 24 h.

2.2 Analytical methods

Moisture and organic matter content, nitrogen Kjeldahl, pH, electrical conductivity and C/N ratio were determined according the standard methodologies proposed by the Test Methods for the Examination of Composting and Compost (TMECC) (USDA, 2001).

Heavy metals content of the compost (Cd, Cr, Cu, Hg, Ni and Pb), *Salmonella* and *E. coli* and nutrients (P and K) were analysed by an external laboratory using standard methods (Applus Agroambiental SA, Lleida, Spain). All tests were performed in triplicate and the results are presented as an average value followed with the corresponding standard deviation.

Dynamic Respiration Index (DRI) and dynamic accumulated cumulative respiration activity (AT_4) were used as a measure of the biological stability. Both parameters were calculated following the methodology proposed by Adani et al. (2006) using the respirometer described in Ponsá et al. (2010). The tests were performed at constant temperature (37ºC) and by setting the airflow constant to preserve the oxygen concentration in the outlet airflow. DRI was expressed as g of oxygen consumed per kg of organic matter (OM) or total solid (TS, equivalent to dry matter) and per hour (g O_2 kg^{-1} OM or TS h^{-1}). DRI is calculated from the average value of 24 instantaneous respiration indices obtained during the most active 24 hours of biological activity. AT_4 was expressed as g of oxygen consumed per kg of organic matter or total solids (g O_2 kg^{-1} OM or TS), and it is also presented as an average of a triplicate measurement. The respiration methodology protocol used establishes that the standard deviation of triplicates can never be higher than 20%, otherwise it is discarded. Detailed information of both methods can be found elsewhere (Ponsá et al., 2010). This test presents some differences with other international standards, for instance, the temperature used and the presence of dynamic conditions. These points should be considered when comparing these values with other protocols and stability limits.

2.3 Statistical analysis

Statistical analysis was based on one way analysis of variance (ANOVA) to calculate the statistical differences of each type of compost analyzed. In some cases, Kruskal-Wallis one way analysis of variance on ranks has been used when it was indicated by the normality test. All statistical tests were evaluated at the 95% confidence level.

3. Results and Discussion

3.1 Compost quality: home versus industrial compost

Physicochemical parameters, heavy metals and nutrient content, and stability parameters were analyzed in a large number of composts from home and industrial composting systems processing exclusively source separate collected organic fraction of MSW. The final characterization of home and industrial composts is presented in Table 1. Statistically significant difference was found between the moisture content in both groups. Home composts presented high levels of moisture than industrial composts, although both values are close to the range (30-40%) proposed in the regulation proposal for organic fertilizers in Spain (Real Decreto 506/2013). The aeration of the bin composter is crucial for removal moisture because frequently thermophilic temperatures are not reached during the process. Alternatively, industrial composts were drier due to a more efficient aeration and the achievement of sustained thermophilic temperatures. However, it is important to note that, sometimes, extremely low moisture values can imply operational problems resulting in a poor stabilization of organic matter.

pH values for both composts were similar and close to 8, which correspond to normal values for the OFMSW compost (Manios, 2004). Contrarily, there was a statically significant difference between both groups of compost in electrical conductivity (EC), being higher in the industrial compost, with a mean value of 7.2 dS cm^{-1}. Composts from MSW, although for source separate collected OFMSW, can present a relatively high level of inorganic salts compared with other substrates (sludge, agriculture wastes, etc.). This can be due to the high degree of decomposition of organic materials, especially rich in protein, which leads to the accumulation of various water soluble salts (Manios, 2004; Farrell et al., 2009). Although there is no limit in compost application in relation to EC, compost with high EC content can present a phytotoxic behaviour affecting seed growth when used in large amounts (Manios, 2004).

Organic matter, nitrogen, phosphorous and potassium contents were similar for home and industrial compost. Only in C/N ratio a significant difference was found between both

groups of compost. Nevertheless, both values (16 and 11 for home and industrial composts, respectively) were lower than 20 as indicated in the Spanish regulation (Real Decreto 506/2013).

One of the key parameters of compost quality, which limits its use as organic amendment, is the heavy metals content. Table 1 shows the metal content in home and industrial composts. There were no significant differences between home and industrial compost for Cd and Hg, and both corresponded to compost Class A according the Spanish regulations. Also for Cr and Pb both composts were classified as Class A, despite there were significant differences between them, being the values from home composting lower than those of industrial composting. For Cu and Ni there were significant differences between the two types of compost, resulting in this case in differences in the compost classification. According to Cu and Ni content, industrial composts are classified as Class B (Class A limits for Cu and Ni are 70 and 25 mg kg^{-1} on a dry basis, respectively), whereas all home composts fit in Class A. The most particular case is Zn content. Both composts corresponded to Class B although home compost only slightly exceeds the limit (Class A limit for Zn is 200 mg kg^{-1}, db).

In conclusion, composts analyzed in this study from industrial facilities correspond to Class B due to Cu, Ni and Zn content. Composts obtained from home composting correspond to Class B due to Zn content, but in this case, it is important to note that there are a large number of samples that are within the limits of Class A for the rest of the metals. Other authors have reported similar values for Zn in home and industrial composts (Smith, 2009). Various authors argue that food, processed foods and green wastes are an important source of heavy metals and, due to the mineralization of organic matter during the composting process, compost from the OFMSW can present a high content of metals exceeding the regulations levels. In fact, according to the limit value levels proposed in the European Quality Assurance for Compost and Digestate (European Compost Network, 2011) and taking into account aspects such as the protection of the environment and consumers, both types of composts are suitable for use. Limits for Cu, Ni and Zn content are respectively 200, 40 and 600 mg kg^{-1} in dry basis. These proposed limits were obtained from a study comparing quality compost from source separate

collected OFMSW. In any case, heavy metals concentration in composts produced from source separate collected OFMSW are lower than those found in the compost from mechanically-sorted MSW organic fraction (Smith, 2009; López et al., 2010).

DRI and dynamic AT_4 values for home and industrial composts are also presented in Table 1. For a more complete vision, boxplots with all data analysed are presented in Figure 1 a) and b). Significant differences were found between the two types of compost for both parameters. Average DRI for home compost was 0.27 g O_2 kg^{-1} OM h^{-1} whereas for industrial compost was 1.51 g O_2 kg^{-1} OM h^{-1}. As show in Figures 1 a) and b) the distribution of values, the mean and the median values for both parameters are similar. Home composts samples can be considered very stable according the most cited references used for aerobic methods (Barrena et al., 2006). However, mean DRI for industrial composts is higher than 1 g O_2 kg^{-1} OM h^{-1}, being in a range between 0.67 and 2.35. Specifically, this value is suggested as a limit to consider the compost as stable (Adani, 2004; European Commission, 2001). However, just over 25% of values are under these limits and only the 75% are higher than 2 g O_2 kg^{-1} OM h^{-1}.

Clearly, most industrial composts samples were above the stability ranges desired. A more complete study of final material and compost from industrial facilities (point 3.3) focusing on the technology used and the waste treated was done with the aim to compare the degree of stability achieved for each one.

3.2 Influence of individual or collective use in home composting

As commented in point 2.1, samples from home composting were classified according its use and location. Data from compost samples divided into the categories established are summarized in Table 2. Some significant differences were observed in some of the properties analyzed. Moisture content in vermicompost is significantly higher than in the home compost samples and higher than the range recommended in regulations (30-40%). This high level of moisture content is inherent to the process and, as a good practice, an extra time should be given to the material without worms to get drier (Lleó et al., 2013). Moisture content in home compost from schools was also significantly different when compared with home composts from

community, familiar and vermicompost. In this case, the moisture content was extremely lower, well below the quality limits in the Spanish regulation. Also, the organic matter content was significantly lower in home compost from schools than those from other sources. Furthermore, bulk density of home compost from schools is very high considering the low moisture content. One of the practices used in some schools, where the bulking agent is not always available, is to incorporate small quantities of sand or soil to avoid odour problems. A repeated use of this practice can impoverish the compost, and consequently, decreasing the quality of compost as organic amendment. Although no significant differences were found, the content in nutrients (N, P and K) was also lower in composts from school, probably due to the same practice.

Usually, thermophilic temperatures were not reached in home composting. Compared with industrial composting, biomass remains at lower temperatures. Nevertheless, biomass degrades slowly, and the relatively long residence time for the organic matter in home composters allows the natural decay of pathogens to occur (Jasmin and Smith, 2003). *E. coli* and *Salmonella* were determined in samples from home composters. All the composts, regardless the composter location, were sanitized since *Salmonella* was not detected and less than 10 CFU/g of *E. coli* were found.

Regarding the metal content in compost according the different categories established, there were no significant differences between the compost for Cd, Cr, Hg, Ni and Pb, without exceeding the limits for Class A quality. However, significant differences were observed in Cu and Zn. Samples from composters located in schools presented high levels of Cu than the other composters. Also, the average of this group slightly exceeds the limit for Class A. Regarding Zn, school and community categories values were significantly higher than vermicompost, above the limit for Class A.

In general, all the compost obtained with home composting presented a high quality level according all the parameters analyzed. However, it is interesting to observe how a collective use can reduce the quality of some samples, mainly regarding to organic matter, Cu and Zn contents. Accordingly, it is important to inform the users of community composters about the importance of good practices to obtain high quality compost. Additionally, for a

correct management of these composters, it is recommended to define a person responsible for their care.

3.3 Analysis of industrial composts from different industrial composting facilities. Influence of treatment technology on compost stability

The comparison between home and industrial composts in point 3.1 has shown the relatively poor level of stability reached in industrial composts. In last years, our research group has analyzed DRI and dynamic AT_4 indices in a large number of composts and final products from industrial facilities where different operational processes were implemented. These data has also been used in this paper with the aim to provide more information about the stability of industrial composts and/or final products.

DRI and AT_4, expressed on a dry matter or organic matter basis, of 35 samples from industrial composts in Spain are represented in the boxplot of Figure 2. As shown in Figure 2a, the mean and median values for DRI are similar. It implies that approximately 50% of the samples analyzed presented DRI values above 1.5 g O_2 g kg^{-1} OM h^{-1}, far from the stability limit suggested in the literature (1.0 g O_2 g kg^{-1} OM h^{-1}), although there were an important number of well-stabilized samples (more than 25%). For both forms of expression, the distribution of boxplots was similar, and the mean and median values were coincident. Also, it is interesting to observe the high dispersion of outlier points in the boxplots, indicating both, facilities with important deficiencies and well-operated plants.

Figure 2b shows dynamic AT_4 on a dry matter and organic matter basis for the samples analyzed. In this case, an asymmetrical distribution in boxplots can be observed, especially for AT_4 on dry matter basis. 50% of the samples analyzed were lower than 50 g O_2 kg^{-1} TS and were concentrated in a narrow range of values. The different distribution in boxplots can be explained considering the information that each respiration parameter (DRI and AT_4) provide. While AT_4 quantifies the biodegradable organic matter content of a given sample, DRI is a measure of the biodegradability rate, being high or moderate (Ponsá et al., 2010). These parameters are correlated for stable materials and when their origin is similar. For different

types of wastes and when they presents a high level of biodegradable matter, the ratio between these parameters is variable and longer respiration tests are required (Ponsá et al., 2010; Puyuelo et al., 2011). Thus, the analysis of boxplots suggests the existence of samples with little amount of organic matter, but still active. For this reason, although the biodegradability rate can be high, total oxygen consumed in four days is comparatively lower because the total biodegradable organic matter content is low. These data shows the complementary character of the two respiration parameters (DRI and AT_4) and the different information that both indices provide.

DRI and AT_4 of samples classified into different systems of composting are included in boxplots of Figure 3. Regarding the samples from OFMSW compost, turned windrows samples (OF-MSW_I) present the lower values of DRI and AT_4. 25% of the samples are below 0.35 g O_2 kg^{-1} OM h^{-1}. Also, an important quantity of samples of the first quartile were below 1 g O_2 kg^{-1} OM h^{-1} indicating that an important part of the samples treated with turned windrows were well stabilized with this system. However, there were also samples that were not well stabilized. The high variability observed highlights how the different way of operation (watering, turning frequency, etc.) can affect the final compost stability.

Compost from the OFMSW samples obtained in more complex technologies present higher levels of biological activity than expected. Only 25% of the samples presented a DRI below 1 g O_2 kg^{-1} OM h^{-1}. Additionally, only 25% of the samples are higher than 2 g O_2 kg^{-1} OM h^{-1}, showing a more symmetrical distribution than the first group analyzed.

From these data, it can be concluded that simple composting technologies, as turned windrows, achieve the most stabilized composts, when properly conducted. However, the high variability and the high DRI of some samples observed in this group (almost 25% of the samples were higher than 2.5 g O_2 kg^{-1} OM h^{-1}) indicate that the process control is inefficient and should be improved, especially regarding the process time necessary to assure a stable product. For more complex composting technologies, the results show a low level of efficiency in the process indicating that, in general, operational conditions need to be improved to achieve proper stability values. However, some samples presenting low biological activity were found, indicating that, obviously, complex facilities have the potential to get stable products, but some

deficiencies in process control need to be overcome (Ponsa et al., 2008, Pognani et al., 2010, 2011b, 2012). Also, it is important to take into account that the input into composting facilities (OFMSW) shows some variability. In a recompilation work, where more than 30 samples were analysed, Pognani (2011a) found a range from 2.2 to 6.7 g O_2 kg^{-1} TS h^{-1} for DRI and 191 to 388 g O_2 kg^{-1} TS for dynamic AT_4 from source separate collected organic fraction. This variability can imply the necessity to adjust processing times and other aspects according the input material for reaching the same grade of stability in all the final compost.

Processed samples from mechanically separated organic fraction in MBT facilities present the highest values of DRI (Figure 3a), showing that in some cases practically all the organic biodegradable matter was not degraded. Composting and MBT facilities have different purposes. Source separate collected organic waste is composted to produce quality products while MBT is used to stabilize wastes that, after source separation, do not contain most of the easily biodegradable organic fraction (Slater and Frederickson, 2001). The potential end uses of these materials have to consider its particular properties and one of the best options is land remediation and restoration schemes (Farrell and Jones, 2009). Anyway, a minimal degree of stability should be reached to avoid environmental impacts (odours, emissions, leachates, etc.) when used.

End products derived from sludge composting resulted in the lower DRI values. However, regarding the high variability of sludge sources and treatments it is necessary to know the initial DRI values to interpret these results. Therefore, some sludge and manure have an initially lower DRI values than the OFMSW (Ponsá et al., 2010; Barrena et al., 2011). When comparing different substrates it is necessary to analyze the reduction of DRI and/or AT_4 to know the efficiency of the treatment used, to have a reliable and fair comparison.

Figure 3b shows boxplots for the dynamic AT_4 index. Although the results were similar to those obtained with DRI some differences, especially for sludge, can be observed. Values of final products from sludge composting were concentrated in a narrow range whereas DRI values in the OFMSW showed more variability. As commented, this difference can be due to the low content of organic matter that some samples presented. Despite this low content, the organic

matter can be easily biodegradable, and consequently the oxygen uptake rate, measured as DRI, can be high. Also, although less pronounced, different distribution for both groups of the OFMSW can be observed.

Certainly, compost application requires a stable product for protecting the soil. Stability measures should allow knowing the degree of biodegradability of the organic matter that compost contains. Large amounts of compost with low organic matter (low AT_4) but still easily biodegradable (high DRI) does not contribute to improve soil conditions or to mitigate the effects of GHG emissions. However, it is important to keep in mind that stability is just one of several parameters for determining compost quality, and it does not describe completely the quality of organic matter. Goal of composting is not only to achieve a low content of organic matter but a high content of stable organic matter (such as humic acids).

4. Conclusions

A large amount of composts from home and industrial composting were analysed and compared. There were no significant differences in chemical parameters related to its agronomic use like organic matter and nutrients content. However, there were significant differences in some metal contents and especially in the level of stability achieved. The content of some metals was higher in industrial compost than in home compost. Cu, Ni and Zn contents classifies industrial composts in Class B (Spanish regulation). However, some home compost samples also presented a Zn level that slightly exceeds Class A limit. Regarding the use of individual or collective home composters, it was observed that composters located in schools presented a lower quality.

Stability, measured as a DRI and dynamic AT_4, is the most important parameter where significant differences were found between the composts analysed. Compost application requires a stable product for protecting the soil and gets all his benefits. This study on stability

of samples from the OFMSW shows the potential of the current technologies to achieve appropriate values of stability, although it depends on the proper control of the composting process. In reference to compost stability from different processes (home or industrial), this study demonstrates that home compost, if properly managed, can achieved a level of stability similar or even better to that of industrial compost, especially when the composting technology is not well managed. This implies a great effort in some composting plants to improve the quality of industrial compost in terms of stability.

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Tables

Table 1. Mean properties of home and industrial composts analysed. Note that for industrial composting only the final material derived from source-selected OFMSW has been included. Mean values with the same letter in the same file are not significantly different from each other.

Properties	Home composts (27 samples)	Industrial composts (25 samples)	Target value/upper limit
Moisture (%, wb)	44 ± 15 a	31 ± 9 b	<40[a]
pH	7.7 ± 0.5 a	7.9 ± 0.7 a	6-8 (<9)[b]
EC (dS m^{-1})	3.9 ± 2.9 a	7.2 ± 3.6 b	0.6 (<1.5)[b]
OM (%, db)	57 ± 18 a	52 ± 12 a	>35[a]
TNK (%, db)	2.2 ± 0.9 a	2.6 ± 0.8 a	No value
P (%, db)	0.8 ± 0.4 a	1.0 ± 0.4 a	No value
K (%, db)	1.4 ± 0.9 a	1.5 ± 0.6 a	No value
C/N ratio	16.0 ± 7.4 a	11.0 ± 2.9 b	<20[a]
Cd (mg kg^{-1}, db)	0.3 ± 0.2 a	0.4 ± 0.2 a	0.7 (Class A)[a] 2 (Class B)[a] 3 (Class C)[a]
Cr (mg kg^{-1}, db)	19.3 ± 11.0 a	39.3 ± 39.6 b	70 (Class A)[a] 250 (Class B)[a] 300 (Class C)[a]
Cu (mg kg^{-1}, db)	53.1 ± 37.9 a	83.5 ± 35.8 b	70 (Class A)[a] 300 (Class B)[a] 400 (Class C)[a]
Hg (mg kg^{-1}, db)	0.1 ± 0.2 a	0.1 ± 0.1 a	0.4 (Class A)[a] 1.5 (Class B)[a] 2.5 (Class C)[a]
Ni (mg kg^{-1}, db)	11.3 ± 5.5 a	31.6 ± 42.1 b	25 (Class A)[a] 90 (Class B)[a] 100 (Class C)[a]
Pb (mg kg^{-1}, db)	24.2 ± 17.3 a	37.0 ± 18.9 b	45 (Class A)[a] 150 (Class B)[a] 200 (Class C)[a]

Zn (mg kg^{-1}, db)	204 ± 127 a	250 ± 125 b	200 (Class A) [a] 500 (Class B) [a] 1000 (Class C) [a]
DRI (g O_2 kg^{-1} OM h^{-1})	0.27 ± 0.16 a	1.51 ± 0.84 b	1 g O_2 kg^{-1} OM h^{-1} [c]
AT_4 (g O_2 kg^{-1} OM)	8.4 ± 8.3 a	113.5 ± 72.3 b	No value

Abbreviations: wb: wet basis; db: dry basis; OM: organic matter; TNK: total nitrogen Kjeldahl; EC: electrical conductivity; DRI: dynamic respiration index; AT_4: cumulative respiration activity

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

[b] Target values suggested in "Guidelines for the specification of quality compost for use in growing media" (Wrap, 2011).

[c] Limit proposed in "Biological Treatment of Biowaste (2nd Draft)" (European Comision, 2001).

Table 2. Mean properties of home compost sample in accordance with the location of the composters. Mean values with the same letter in the same file are not significantly different from each other.

Properties	Composts from each type of composter				Target value/upper limit
	Vermicompost (5)	School (5)	Community (8)	Family (9)	
Moisture (%,)	74.5 ± 10 a	22.3 ± 8 b	50.3 ± 7 c	50.0 ± 11 c	<40[a]
BD (g cm^{-3})	0.7 ± 0.3 a	0.7 ± 0.1 a	0.5 ± 0.1 a	0.5 ± 0.2 a	400-500 /550[b]
pH	8.0 ± 0.6 a	8.1 ± 0.4 a	7.7 ± 0.5 a	7.6 ± 0.5 a	6-8/9[b]
CE (dS m^{-1})	2.6 ± 2 a	5.3 ± 5a	3.3 ± 2 a	3.5 ± 2 a	0.6/1.5[b]
OM (%, db)	71.6 ± 11 a	34.8 ± 16 b	58.8 ± 14 a	68.1 ± 11 a	>35[a]
NTK (%, db)	2.6 ± 0.3 a	1.7 ± 1.0 a	2.5 ± 0.9 a	2.3 ± 0.8 a	No value
P (%, db)	0.9 ± 0.4 a	0.7 ± 0.4 a	0.9 ± 0.4 a	0.8 ± 0.4 a	No value
K (%, db)	2.5 ± 1.0 a	1.1 ± 0.8 a	1.6 ± 0.8 a	1.5 ± 0.9 a	No value
C/N ratio	14.9 ± 3.5 a	16.3 ± 10.9 a	14.1 ± 6.0 a	17.6 ± 6.0 a	<20
Cd (mg kg^{-1}, db)	0.3 ± 0.2 a	0.4 ± 0.4 a	0.3 ± 0.2 a	0.2 ± 0.2 a	0.7 (Class A)[a]2 (Class B) [a] 3 (Class C) [a]
Cr (mg kg^{-1}, db)	14.1 ± 12 a	21.0 ± 13 a	19.4 ± 10 a	18.3 ± 12 a	70 (Class A) [a] 250 (Class B) [a] 300 (Class C) [a]
Cu (mg kg^{-1}, db)	48.8 ± 25 a	74.2 ±69 b	52.1 ± 25 a	42.2 ± 18 a	70 (Class A) [a] 300 (Class B) [a] 400 (Class C) [a]
Hg (mg kg^{-1}, db)	0.1 ± 0.1 a	0.1 ± 0.1 a	0.1 ± 0.2 a	0.2 ± 0.3 a	0.4 (Class A) [a] 1.5 (Class B) [a] 2.5 (Class C) [a]
Ni (mg kg^{-1}, db)	9.9 ± 6.6 a	13.0 ± 6.9 a	11.3 ± 4.3 a	10.4 ± 6.1 a	25 (Class A) [a] 90 (Class B) [a] 100 (Class C) [a]

Pb (mg kg^{-1}, db)	11.9 ± 9.9 a	36.4 ± 27.5 a	21.3 ± 12.2 a	19.8 ± 11.8 a	45 (Class A) [a] 150 (Class B) [a] 200 (Class C) [a]
Zn (mg kg^{-1}, db)	88.2 ± 21.8 a	228.4 ± 157.8 b	252.4 ± 168.4 b	153.4 ± 39.0 ab	200 (Class A) [a] 500 (Class B) [a] 1000 (Class C) [a]
Salmonella	Absence	Absence	Absence	Absence	Absence in 25 g
E. coli (CFU/g)	<10	<10	<10	<10	<1000
IRD	0.33 ± 0.13 a	0.19 ± 0.12 a	0.26 ± 0.14 a	0.27 ± 0.21 a	1 g O_2 kg^{-1} OM h^{-1} [c]
AT_4	9.1 ± 7.0	7.3 ± 6.5	8.5 ± 9.0	8.6 ± 10.3	No value

Abbreviations: wb: wet basis; db: dry basis; OM: organic matter; BD: bulk density; TNK: total nitrogen Kjeldahl; EC: electrical conductivity; DRI: dynamic respiration index; AT_4: cumulative respiration activity

[a] Regulation proposal for organic fertilisers in Spain (Real Decreto 506/2013)

[b] Target values suggested in "Guidelines for the specification of quality compost for use in growing media" (Wrap, 2011).

[c] Limit proposed in "Biological Treatment of Biowaste (2nd Draft)" (European Commission, 2001).

Legends to Figures

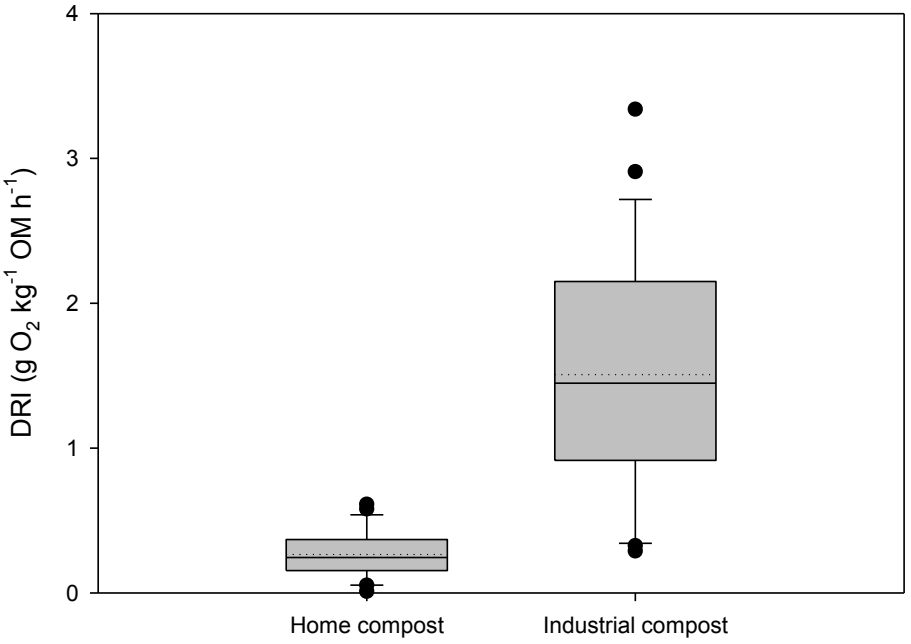
Figure 1. DRI (a) and dynamic AT_4 (b) boxplots for home and industrial composts. Discontinuous line in boxplot indicates mean values.

Figure 2. DRI (a) and dynamic AT_4 (b) boxplots for industrial compost and final products from MBT process and sewage sludge composting on dry matter and organic matter basis. Discontinuous line in boxplot indicates mean values.

Figure 3. DRI (a) and dynamic AT_4 (b) boxplots for industrial composts and final products regarding technology used: turned windrows (OF-MSW_I) and in-vessel composting (OF-MSW_II) and waste origin: (OFMS-MSW and Sludge). Discontinuous line in boxplot indicates mean values.

Figure 1.

a)


DRI (g O_2 kg^{-1} OM h^{-1})
4
3
2
1
0
Home compost
Industrial compost

b)

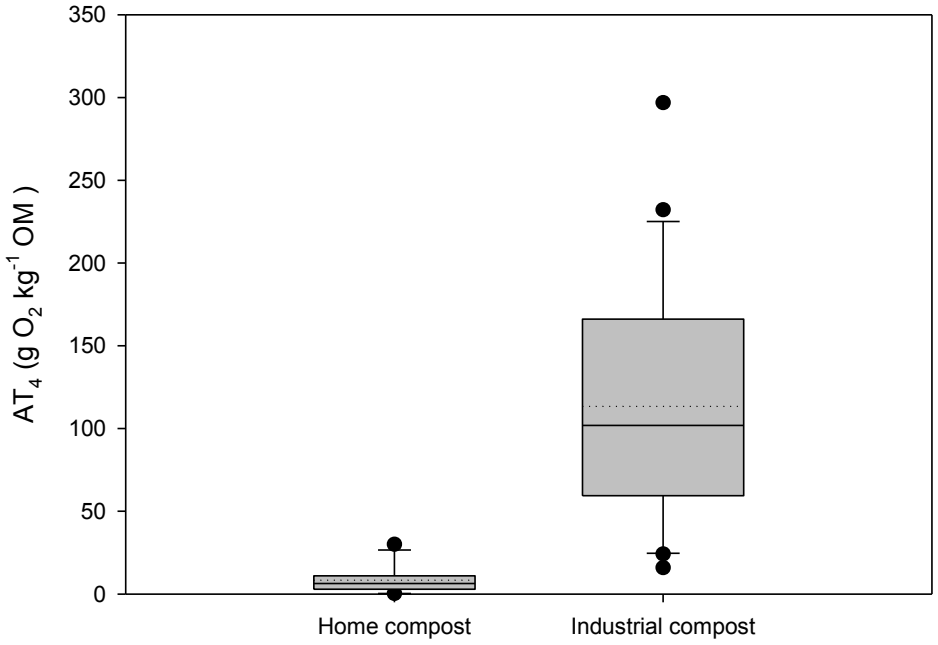
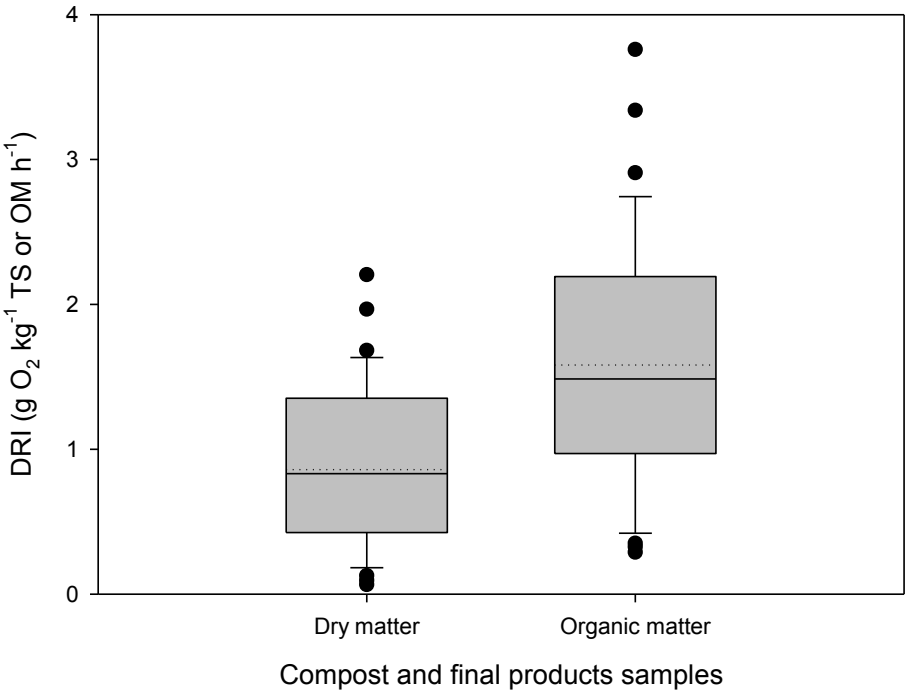

AT_4 (g O_2 kg^{-1} OM)
350
300
250
200
150
100
50
0
Home compost
Industrial compost

Figure 2.

a)


DRI (g O_2 kg^{-1} TS or OM h^{-1})
0
1
2
3
4
Dry matter
Organic matter
Compost and final products samples

b)

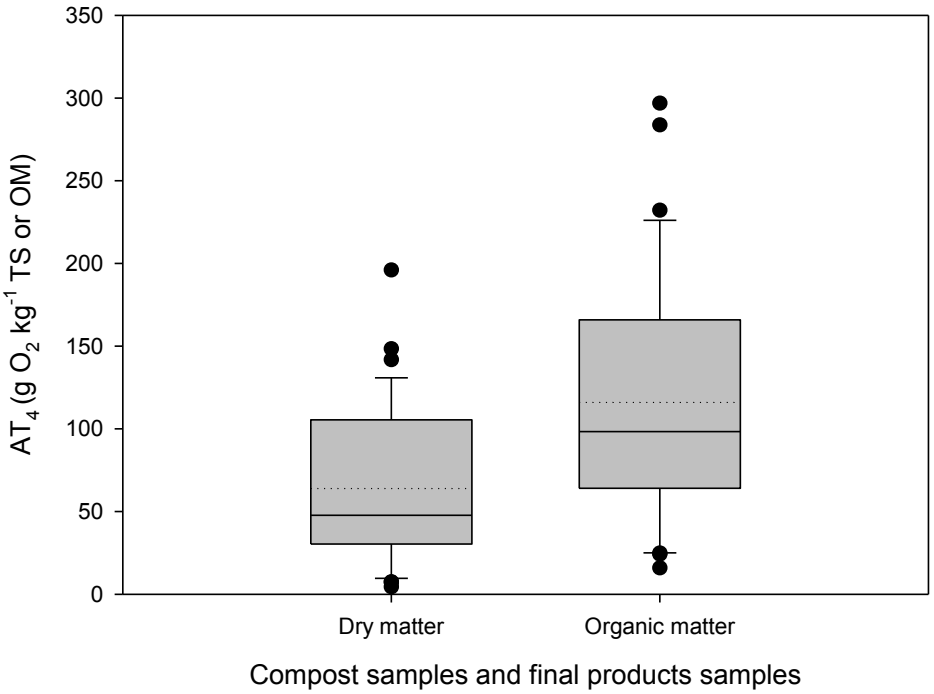
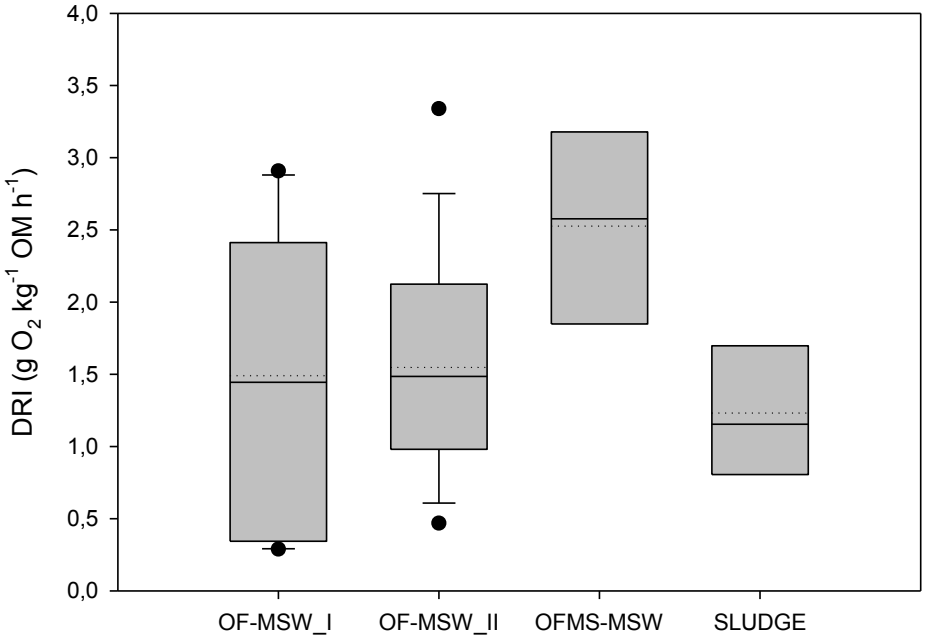
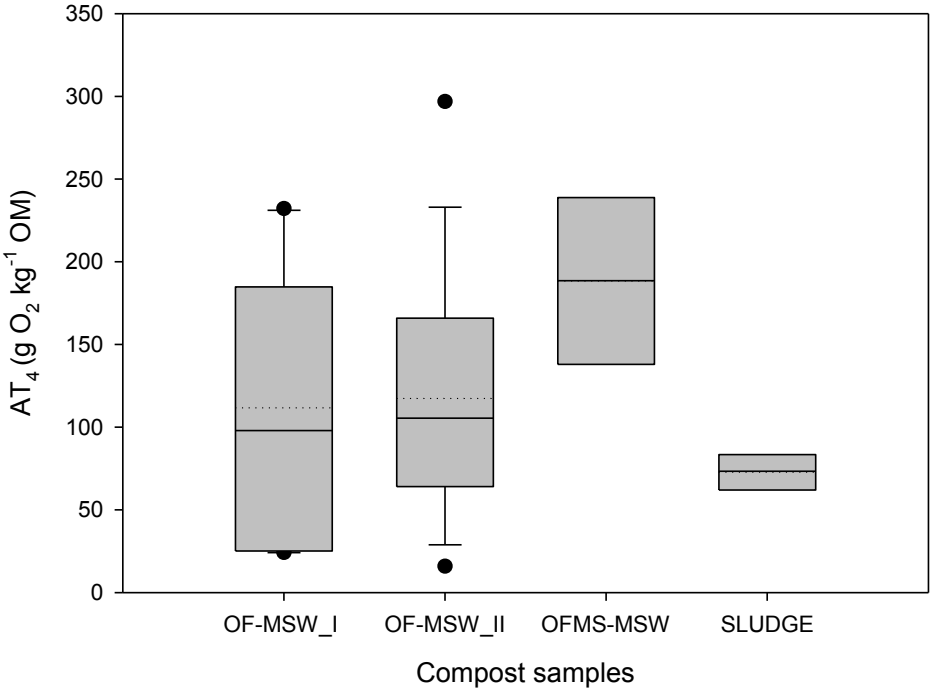

AT_4 (g O_2 kg^{-1} TS or OM)
0
50
100
150
200
250
300
350
Dry matter
Organic matter
Compost samples and final products samples

Figure 3.

a)


4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
DRI (g O2 kg-1 OM h-1)
OF-MSW_I
OF-MSW_II
OFMS-MSW
SLUDGE

b)


350
300
250
200
150
100
50
0
AT4 (g O2 kg-1 OM)
OF-MSW_I
OF-MSW_II
OFMS-MSW
SLUDGE
Compost samples