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Co-composting of poultry manure with other agricultural wastes. Process performance and compost horticultural use

Pedro Federico Rizzo[b], Virginia Della Torre[b], Nicolás Ivan Riera[b], Diana Crespo[b], Raquel Barrena[a], Antoni Sánchez[a*]

[a] Departamento de Ingeniería Química, Universitat Autònoma de Barcelona, 08193-Bellaterra (Cerdanyola del Vallès), Spain.

[b] Laboratorio de Transformación de Residuos, IMyZA, Instituto Nacional de Tecnología Agropecuaria. De los Reseros y las Cabañas S/N, Castelar, Buenos Aires, Argentina.

*Corresponding author:

Antoni Sánchez

Tel.: +34 935811019

Fax: +34 935812013

Email: antoni.sanchez@uab.cat

Abstract

The aim of this work was to evaluate the composting process of poultry manure mixed with other complementary organic wastes. Two mixtures (Treatment 1 and 2) were prepared with corn bare cobs, sawdust, shavings and manure. Temperature, pH, electrical conductivity, organic matter loss, total organic carbon, solved organic carbon, N loss, ammonium and nitrate concentration, laccase activity and respiration indices were analyzed. These variables showed similar tendencies during the composting process for both treatments. A peak of biological activity, organic matter mineralization and salts release were observed after 6 days of process. Treatment 2 showed higher concentration of solved organic carbon and higher organic matter loss than those of the mixture with less manure (Treatment 1). Laccase activity increased when solved organic carbon dropped. Compost from Treatment 1 showed lower phytotoxic effects than that of Treatment 2, probably due to a low salt content. As conclusion, it was observed that 60 % content of poultry manure in the mixture does not affect the composting process. However, the final product is less adequate for agricultural purposes than a mixture with less content of manure. Finally, it can be stated that these wastes valorization in the form of compost adds value to the materials, closing the biogeochemical nutrients cycle.

Keywords: poultry manure; decomposition; composting; compost quality.

1. Introduction

Poultry activity is steadily growing worldwide. In Argentina, during 2010, egg production showed a 4 % increase compared to 2009 [1].

Production increase can be partly explained by the degree of intensification that has been implemented in the production systems in last years. This kind of systems causes large accumulations of manure. This accumulation, which does not have a clear destination in the Pampean region of Argentina, poses several threats to the environment. The uncontrolled decomposition of hen manure releases NH_3, N_2O and CH_4 to the atmosphere. Dekker et al. [2] found that the average emission per layer was 144 ± 13.5 g y^{-1} for NH_3, 1.11 ± 0.33 g y^{-1} for N_2O and 27.4 ± 5.19 g y^{-1} for CH_4. These wastes could pollute soil and water if periodically applied as a direct organic amendment (without treatment) to soils.

Stabilization of organic wastes through composting can prevent environment damage and present a positive balance when applied to soil [3]. Although composting has been extensively studied, to the best of our knowledge, there are no published references on the composting of wastes produced in the Pampean region. This region is facing the problems of an important economical growth that must be sustainable regarding the waste management strategies that will be applied in the future. However, the composting process of manure requires the presence of an adequate bulking agent and an extra source of carbon for balancing the C/N ratio. The benefits of this strategy are a reduction in nitrogen losses and a high compost agricultural value.

Therefore, the aim of this work was to evaluate different mixtures of wastes that may increase the use of poultry manure in the composting process with other wastes of high production in the region. The resulting mixture must permit a correct development of the

composting process and an adequate evolution of the main parameters, where the waste is generated, and without a big investment. A secondary objective of this study is to explore the possibility of using the compost obtained as growing media for horticultural use.

2. Materials and Methods

2.1. Composting experiments

The experiments were carried out in the IMyZA, INTA (Buenos Aires, Argentina).

The poultry manure (PM) was obtained from automatized sheds of hens for egg production of the Zucami® type, located in a farm in Mercedes, Buenos Aires (34° 42´43.18´´ S; 59° 31´19.91´´O). This waste was mixed with corn bare cobs (CBC), sawdust (SA) and shavings (SH). The wastes used came from the same zone (Table 1).

Percentages in volume for Treatment 1 (T1) contained 40% PM (53% in dry mass), 20% CBC (9% in dry mass), 20% SA (24% in dry mass) and 20% SH (14% in dry mass), whereas treatment 2 (T2) contained 60% PM (71% in dry mass), 20% CBC (8% in dry mass) and 20% SA (21% in dry mass) Table 1 shows the characterization of wastes and initial mixtures to be composted.

Mixtures were homogenized using a 0.5 m^3 capacity mixer at the beginning of the trial. Piles were constructed in a trapezoidal shape (1.5 m height, 2 m wide and 2 m long). Each treatment was carried out using three replicates of 2 m^3 each, in piles of an initial height of 1.5 m and approximately 1 Mg of total weight. The composting process lasted 83 days.

Composting piles were manually turned every 3 days during the first active decomposition phase of the process and every 5 days when the pile temperature was similar

to environment temperature (maturation stage). The moisture content was maintained through irrigation and taking into account the local precipitation. Samples (about 10 kg) were weekly taken from the composting piles at three different locations (days 0, 6, 13, 21, 27, 34, 41, 48, 55, 62, 69, 76 and 83) and homogenized to obtain a representative aliquot of 1 kg per pile [4]. Table 2 summarizes the variables measured each sampling day.

2.2. Composting monitoring and compost characterization

Environment temperature and local precipitation were daily recorded at the meteorological station of INTA.

Seventeen parameters suggested by the TMECC [4] were monitored during the composting trials: temperature, pH, electrical conductivity (EC), moisture content, carbon to nitrogen ratio (C/N), bulk density (δ), total phosphorous (TP) and dissolved reactive phosphorous (DRP), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), total organic carbon (%TOC), solved organic carbon (%SOC), dry matter (%DM), organic matter (%OM), total nitrogen (N_T) and ashes (%Ash) percentages. The percentages of OM and N_T losses were determined using the equations 1 and 2 as suggested by Paredes et al. [5]:

$$\text{OM loss (\%)} = 100 - 100[X_1 (100 - X_2)]/[X_2 (100 - X_1)] \quad \text{Eq. (1)}$$

$$N_T \text{ loss (\%)} = 100 - 100\ (X_1\ N_2)/(X_2\ N_1) \quad \text{Eq. (2)}$$

where: N_1 and N_2 are the initial and final N_T concentrations and X_1 and X_2 are the initial and final ash concentrations, respectively.

Ammonium (NH_4^+) and nitrate (NO_3^-) concentrations were measured by means of the micro distillation method [6].

Laccase enzymatic activity (LEA), expressed as µmol min^{-1} g DM^{-1}, was determined spectrophotometrically (420 nm) by measuring the oxidation of 0.5 mM ABTS (2.2´-azinobis (3-ethyl benzothiazoline-6-sulfonate) in 0.1 M acetate buffer, pH 3.6 [7].

Biological activity was measured using the static respirometric index based on the OM content (SRI) [4]. A static respirometer was built according to the original model described by Iannotti et al. [8] and modified following the TMECC [4] recommendations. The drop of oxygen content in a flask containing a sample was monitored with a dissolved oxygen meter (Lutron 5510, Lutron Co. Ltd., Taiwan). The rate of respiration of the sample (Oxygen Uptake Rate, based on OM content) was calculated from the slope of oxygen level decrease according to the standard procedures [8].

Ecotoxicology bioassays were carried out with the final composts, using two species: *Lactuca sativa* (lettuce: $_L$) and *Raphanus sativus* (radish: $_R$). Seed germination and the root elongation were measured, according to US EPA standardized protocols [9]. These measurements were used to calculate the germination index (GI) according to Zucconi et al. [10, 11] and the root growth index (RGI) [12].

Considering the observed toxicity effect, RGI values have been classified within 3 categories: Root elongation inhibition (I): $0 < RGI > 0.8$; Non-significant effects (NSE): $0.8 \leq RGI \geq 1.2$; Root elongation stimulation (S): $RGI > 1.2$ [13].

According to Barbaro et al. [14], the results from the agricultural valorization of the produced compost were analyzed. The use of different substrates formulated with T1 (C1),

T2 (C2) and pine bark (PB) composts in different proportions were evaluated in the *Salvia splendens* L. and *Impatiens walleriana hybrids* Hook. for plants development.

2.3. Statistical analyses

Variables were analyzed by ANOVA and with the Kruskal-Wallis non parametric test when the data did not satisfy the assumptions. A p value of 0.05 was considered to establish significant differences. The variables measured in the final composts were analyzed by principal components analysis. Statistical analyses were run using the statistics program InfoStat version 2010, Grupo InfoStat, Córdoba, Argentina.

3. Results and Discussion

3.1. Physicochemical characterization of composted wastes

The results showed in Table 1 indicate that the principal limitations of PM for decomposition in composting are a slightly alkaline pH, a high salt content, high δ and low porosity [15] and low C/N ratio. To overcome these limitations and improve the aerobic biodegradation of PM, other three typical abundant wastes in the egg productive region were mixed with PM. The addition of SA, CBC and SH to PM improved the porosity and the C/N ratio of the mixtures proposed (Table 1).

3.2. Evolution of routine parameters of the composting process

Both treatments showed the typical composting thermophilic profile [3]. According to Ugwuanyi et al. [16], temperature above 45°C could be considered as thermophilic and suitable for killing pathogenic microorganisms. They highlighted the need of reaching the

minimum temperature of 45°C, for at least 5 days. In this assay, the thermophilic phase lasted 35 and 37 days for T1 and T2 respectively, which is a clear indication of compost sanitation. Within the thermophilic phase, two peaks were observed in both treatments. During the first weeks, the temperature increased to 60-65°C. T1 remained within this range for 13 days, whereas in T2 it lasted 8 days. The maximum temperature was reached at day 15 and then a drop in this parameter was observed. This moment corresponded to a 5-days precipitation period, which could have favored the temperature decrease. A new temperature rise was observed from day 25 until day 40. Then, the composting piles started to cool down to a second stage of maturation, from day 55, when temperature was similar to that of the environment (Fig. 1).

The initial pH values in both treatments were close to the upper limit of the range (6-8) suggested by Rink [17] as suitable for aerobic degradation. T1 showed an average initial value of 8.3 ± 0.2, while the initial value for T2 was 7.9 ± 0.3 (Table 1). Although T2 presented more amount of PM, no significant differences were observed in pH for both mixtures. The alkaline condition of both mixtures was a consequence of the high content of PM, which presents an alkaline pH (Table 1). The evolution of this parameter was similar in both treatments (Fig. 2a). Extreme pH levels were 7.8 and 9.0 for T1 and 7.9 and 9.0 for T2. Bustamante et al. [18] related the pH increase during the first phase with the high concentration of NH_3 released from proteins and aminoacids decomposition. The highest pH values (T1: 8.9 ± 0.1, T2: 9.1 ± 0.1) recorded in the first stage of the composting process also correlated with high temperature (T1: 63.0 ± 0.5ºC, T2: 61.0 ± 0.5ºC) reached the same days (Fig. 1), which again are associated to the NH_3 formation and release [19]. Later, the NH_4^+ profiles and N loss during the process for both treatments support the

hypothesis of the formation and release of NH_3 during the first part of the process, which presents an exponential correlation with temperature in the first active decomposition stage of composting, and a soft linear evolution during the maturation stage [19].

Moisture percentage of the composting piles was adjusted based on the results of the squeeze test (4) by watering. When it was necessary, water was sprayed over the material and mixed thoroughly. Fig. 2b show the moisture profiles for T1 and T2 and the days when the piles were watered. Rainfall days are also shown in Fig. 2b. The cumulative precipitation was of 216.3 mm after 83 composting days. The initial moisture percentage was similar (72 %) for T1 and T2 (Table 1). Both values were over the optimum moisture percentage range of 40-60% [3]. However, the results obtained by Petric et al. [20] suggest that the initial moisture percentage should be around 69%, when composting PM. For this type of wastes, Ahn et al. [21] found that the optimum moisture percentage was in the range of 60-80% depending on the water holding capacity. In the case under study, as seen in Fig. 2b, the moisture content decreased to 60% in the first weeks of the process, showing a the correct evolution of the process. In both treatments, the moisture percentage remained within the range of 52-72%. An increase of the amount of water content in the piles was observed from day 40, corresponding to 3 consecutive days with a cumulative precipitation of 55 mm.

The initial EC showed average values of 18.7 ± 4.4 and 21.4 ± 1.6 mS cm^{-1} for T1 and T2, respectively (Table 1). The profile evolution of EC for T1 and T2 is shown in Fig. 2b together with moisture content profiles. This high salt concentration can be related to the high PM content in the mixtures (Table 1). The maximum EC value was recorded 6 days after the beginning of the experiment in both treatments, coinciding with the highest OM

loss and with an important decrease of moisture content. The fast mineralization rate observed between days 6 and 13 could have resulted in the release of salts. Also, mineral salt leaching can contribute to the decrease of EC observed in Fig. 2b. From day 6 on, this parameter decreased to reach a final average value of 2.0 ± 0.5 and 3.4 ± 0.1 mS cm^{-1} for T1 and T2, respectively.

3.3. OM decomposition, biological activity and N dynamics

OM and TOC contents were higher in T2 than T1 due to the higher content of PM in T2 (Table 1). In both treatments the %OM loss was more pronounced during the first weeks of the experiment, together with higher temperatures and a higher biological activity as shown by the SRI values during this period. Fig. 3a shows a progressive drop in the SRI up to day 55 in both treatments. However, from this moment an increase in the biological activity was observed in both treatments. A relative increase of biological activity was also reflected in the temperature profiles and could be due to a partial degradation of more recalcitrant materials [22]. Although we do not have a definitive explanation about this specific period, all the indicators (SRI, temperature, drop of SOC, etc.) seems to show that this could be due to the breakdown of laccase typical substrates [23]. A faster drop in activity was observed for T1 indicating a higher degradation of OM during the first days of the process. Nevertheless, the SRI profile for T2 showed a pronounced drop from the day 20 on, suggesting that biodegradable OM was present in this mixture during a long period of time.

The highest OM loss in T1 (31 ± 1) was observed at day 13, while in T2 it was observed at day 6 (29 ± 2). By day 33, the accumulated percentage of OM loss was of 69 ±

8 for T1 and 78 ± 6 for T2. From this moment on, the OM loss was relatively stable reaching final values of 80 ± 4 for T1 and 84 ± 2 for T2. Ruggieri et al. [24] and Colón et al. [25], also reported high losses of OM during the first phase of the process, followed by a period of slower degradation and respiration activity.

The initial levels of %SOC decreased in both treatments throughout the experiment. Hsu and Lo [26] correlated this reduction to the breakdown of hemicellulose, sugars, phenolic substances, organic acids, peptides and other easily biodegradable substances. Laccase is responsible for the hydrolysis of the main fibers found in organic wastes [23]. In T1, LEA started to increase at day 13, when the SOC was 41.1%, whereas in T2 started to increase at day 27, when the SOC was 35.6 % (Fig. 3b). Both treatments achieved their maximum LEA in different moments. The activity peaked at day 41 for T1, while T2 did it at day 55 (Fig. 3b). These data seems to be related with the biological activity measured with the SRI and could be due to the composition of mixtures. The higher content of SOC in T2 could be delaying the degradation of lignocellulosic materials. Also, T1 was richer in lignocellulosic material (20 % of SH). De Bertoldi et al. [27] have observed similar effects when composting lignocellulosic materials. On this regard, fungi tend to grow in the later stages of composting and have been shown to attack polymers such as hemicellulose, lignin and cellulose. Tiquia [28] found that extracellular enzyme activities were greater in older compost than in younger compost. These previous studies seem to support the observations about the LEA determined for both mixtures.

The N dynamics were similar to that of the OM. The highest decrease in N was detected during the first 6 days, with an average of 32 ± 15 % and 58 ± 10 % for T1 and T2,

respectively, as shown in Fig. 3. Thus, the highest OM loss was recorded during the first 13 days, jointly with a pH close to 9 and high temperature.

These conditions are often coupled with the organic N mineralization and provoke the release of NH_4^+ and NH_3 gas [19]. Fig. 3 shows the coincidence in time of the highest values of N losses with the highest NH_4^+ concentration, which confirm previous research studies [19]. NH_3 generation tends to increase with pH, since uric acid breakdown rise under alkaline (pH > 7) conditions, and the effect of uricase is maximum at pH of 9 [28]. Regarding this, NH_3 emissions can be inhibited by acidic compounds that decrease the conversion of NH_4^+ to NH_3. These compounds can also inhibit enzymes involved in the formation of NH_3, decreasing its production [29]. In this case, the initial content of NH_4^+ in T2 was significantly higher than in T1. Although the NH_4^+ dynamics were similar for T1 and T2; the decrease of NH_4^+ content was significantly delayed in T2. The higher amount of PM in the initial mixture (60%) in T2 could be responsible for this delay.

Regarding the C/N, the initial values were 24 ± 5 and 14 ± 2 for T1 and T2, respectively (Table 1). The C/N evolution of T1 and T2 is shown in Fig. 2a, whereas in Fig. 4 the N loss and NH_4^+ are presented. There is an important increase of C/N ratio on day 6 of process due to by the N loss as previously commented. After this moment, this ratio decreased at the beginning of the composting process, when the OM loss reached its maximum. Comparable results were found by Ferrer et al. [30] and Bustamante et al. [18]. However, it has to be emphasized that most of the published results on composting and the evolution of C/N are referred to the overall C/N, which is chemically determined and can be very different from biodegradable C/N [31]. Accordingly, it is possible that SOC

variations are more reliable to interpret the available carbon present in each mixture, rather than TOC or total OM.

3.4. Compost quality and agricultural valorization

The characteristics of the final composts are summarized in Table 3. In order to compare these properties, the recommended values of the most important parameters for the use compost in growing media [32] and the minimum content of some nutrients according to the Regulation proposal for organic fertilizers in Argentina [33] are included in Table 3.

pH values in both treatments were slightly alkaline. Compost with pH levels close to 8 decreases the heavy metals transference to the food chain, reducing their phytotoxicity potential [12]. On the contrary, the N availability was not affected by pH levels, whereas P was mainly associated to Ca^{2+} ion, resulting in TP and DRP concentrations similar for both treatments, reaching an average availability of 5 ± 1 and 4 ± 1 (%) for T1 and T2, respectively (Table 3).

The EC, Ca, Mg, Na and K contents were significantly higher in the compost obtained in T2, according to the initial amount of manure of this mixture. EC and Ca contents are above the recommend values for growing media [32]. One possible strategy to improve these parameters is to formulate mixtures with wastes with low values of EC.

The final values of C/N (T1: 14.4 ± 0.7 and T2: 13.6 ± 0.8) suggest that both composts have an acceptable maturity level, considering that these values are lower than 20 [29, 32].

The stability limit of the SRI for compost samples is between 0.5 and 1 mg O_2 g^{-1} OM h^{-1} [4, 22, 34]. Both composts reached SRI values below this stability limit, with average values of 0.25 ± 0.05 and 0.45 ± 0.04 mg O_2 g^{-1} OM h^{-1} for T1 and T2, respectively (Table 3).

According to the principal component analyses, the highest values for pH, EC, Ca, Mg, Na, K, N, TP and δ were associated to T2, whereas NO_3^- concentration, C/N, GI_L and GI_R were associated to T1 (Fig. 5). The RGI_L was lower than 0.8 from 25 % in both composts. On the other hand, the RGI_R was lower than 0.8 from 50 and 80 % of the compost T1 and T2, respectively. RGI values below 0.8 indicate inhibitory effects on the root growth [13]. The GI in both species was less affected in T1 compost. Fig. 5 shows that the GI_L and GI_R were inversely correlated to the salt content and the EC. As commented, the mixture with other materials with low salt content can improve the final use of these composts, especially from T2. Domènech et al. [35] compared two composts from two different wastewater treatment plants in several phases of the degradation process. They found that seed emergence was significantly affected by compost dosage but also by the time of composting.

Both composts were mixed with PB compost in 20%, 50% and 80% [14]. The six formulated substrates were also compared with a *Sphagnum* commercial substrate as control. Each substrate was a treatment: 1) 80% C1 + 20% PB; 2) 50% C1 + 50% PB; 3) 20% C1 + 80% PB; 4) 80% C2 + 20% PB; 5) 50% C2 + 50% PB; 6) 20% C2 + 80% PB; 7) Commercial substrate. *Salvia splendens* L. var. red and *Impatiens walleriana hybrids* Hook. f. var. Accent Pink Imp. were used. Each species was grown in the 7 treatments with five replicates.

All substrates total porosity (TPo) exceeded the 80% optimum value [36]. The substrates that showed significantly higher TPo percentages were the ones made of 80 % compost. On the other hand, significant differences were found in the water holding capacity (WHC), being higher in the substrates with 20% and 50% compost. The free airspace (FAS) higher values were found in the substrates with 80% compost. These results suggest the evaluated compost made of poultry manure improves aeration and reduces the WHC of the substrates. However, according to several authors [35,37] all the substrates presented an adequate WHC (24-40%) and a high FAS percentage (20-30%).

Both substrates with 80% compost had the highest pH values (7.9 – 8.3) followed by the substrates with 50% (7.0 – 7.6) exceeding the optimum range established for most cultivated species according to Handreck and Black [38] (pH between 5.5 and 6.3). However, all values are in the range recommended for the use of compost as a growing media [32]. Therefore, the selected cultivated species will finally condition its use, and they will determine the dosage in the mixture with other substrates.

The substrates with 80% C1, 50% and 80% C2 showed EC values higher than 1 dS cm^{-1} (1.1, 1.3 and 1.6 dS cm^{-1}, respectively). If the substrate exceeds this value, it could lead to salinity problems, depending on the plant, environmental conditions, management practices and species characteristics [39].

The plants cultivated in the commercial substrate reached the greatest aerial and radicular dried matter (1.3 g and 0.5 g), followed by the plants developed in both substrates with 20% compost. The substrates with 50% C2 and, 80% C1 and C2 had EC higher than 1 dS m^{-1}. *Salvia splendens* plants grown in the substrates with 80% C2 died three days after

being transplanted. The *Salvia splendens* plants died from an EC of 1.6 dS m^{-1}, while *Impatiens walleriana* died from 2 dS m^{-1} on.

The aerial dried matter chemical analysis showed that both species plants developed in the commercial substrate and in the ones with 20% compost had a higher Ca and Mg concentration and a lower K concentration. On the other hand, the substrates with 80%, 50% C1 and C2 has a higher K content but lower of Ca and Mg. These results suggest that there was an excessive K consumption and Ca and Mg adsorption inhibition [37]. Carmona et al. [39] mentioned the high salinity and the low WHC of most composts as one of the principal disadvantages. They suggested that it is necessary to mix composts with other materials to formulate a substrate.

The substrates formulated with less percentages of C1 and C2 (20%) and with 50% C1 were the ones with a higher WHC and lower salinity, favoring the *Salvia splendens* and *Impatiens walleriana* plants development.

4. Conclusions

It can be concluded that the addition of sawdust, corn bare cobs and shavings to poultry manure improves its porosity, reduces the initial pH and balances its C/N ratio. Regarding the composting process, the thermophilic phase lasted over 30 days in both treatments, favoring pathogen elimination. However, the thermophilic phase was longer in T2 than T1. Differences in the rate of biodegradation were observed in both mixtures.

According to compost characteristics, T1 showed lower phytotoxic effects than T2, probably related with the high salts content of T2. It was found that 60 % of poultry manure content in the mixture has no adverse effect in the composting process. Nevertheless, the

final product shows more agricultural use limitations than a mixture with less poultry manure.

This problematic waste, once composted and in a correct dosage, could be used as a substrate component for ornamental plant cultivation closing the biogeochemical nutrient cycle.

These results suggest that it is necessary further research about strategies to reduce the composting process time, such as the co-compost poultry manure with others wastes. The final use of these composts in agricultural applications is also worthy of investigation.

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Table 1. Characterization of the wastes and the mixtures (T1 and T2).

Parameter	Units	Agricultural Wastes				Treatments	
		PM	CBC	SH	SA	T1	T2
pH		8.0 ± 0.3	6.3 ± 0.0	6.0 ± 0.1	7.6 ± 0.1	8.3 ± 0.2	7.9 ± 0.3
EC	mS cm^{-1}	21.8 ± 0.6	1.3 ± 0.0	1.2 ± 0.0	0.8 ± 0.0	18.7 ± 4.4	21.4 ± 1.6
δ	g L^{-1}	996 ± 41	95 ± 2	165 ± 7	265 ± 12	564 ± 62	663 ± 38
Moisture	%	73.9 ± 0.2	8.4 ± 0.1	10.9 ± 0.1	11.5 ± 0.1	72.4 ± 1.6	71.9 ± 1.0
OM	%	75.3 ± 1.6	96.8 ± 0.9	99.1 ± 0.1	98.9 ± 0.0	73.8 ± 3.0	80.8 ± 6.2
Ash	%	24.7 ± 1.6	3.2 ± 0.9	0.8 ± 0.1	1.1 ± 0.0	26.1 ± 3.0	21.6 ± 2.1
TOC	%	37.6 ± 0.8	48.4 ± 0.4	49.6 ± 0.0	49.5 ± 0.0	36.9 ± 1.5	40.4 ± 3.1
SOC	%	1.5 ± 0.6	0.7 ± 0.0	0.9 ± 0.1	1.4 ± 0.1	48.5 ± 5.8	79.5 ± 11.8
N_T	%	6.2 ± 0.9	2.5 ± 0.1	1.7 ± 0.0	2.1 ± 0.0	1.6 ± 0.4	2.9 ± 0.4
C/N	%	6.2 ± 0.8	19.1 ± 0.2	29.1 ± 0.0	23.5 ± 0.0	23.5 ± 5.7	14.4 ± 2.2

EC = electrical conductivity, δ = density, OM = organic matter, TOC = total organic carbon, SOC = dissolved organic carbon, N_T = total nitrogen, C/N = carbon nitrogen ratio, PM = poultry manure, CBC = corn bare cobs, SH = shavings, SA = sawdust, T1 = treatment 1, T2 = treatment 2.

Figure Captions:

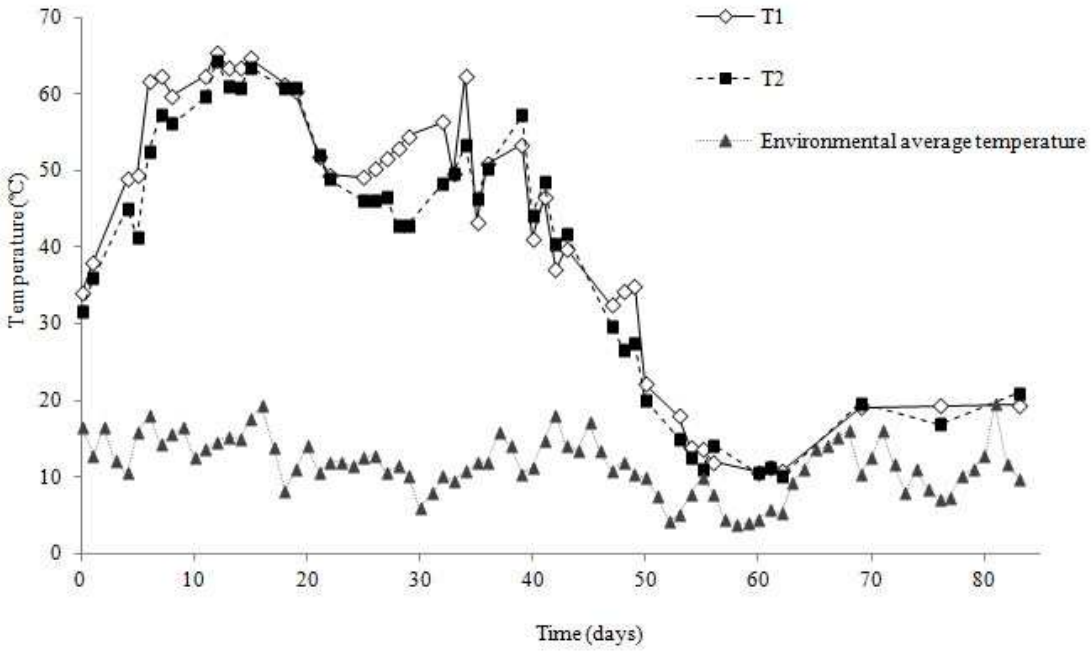
Fig. 1 Temperature evolution of T1 and T2 and environment temperature

Fig. 2 a) pH and C/N ratio evolution in T1 and T2; **b)** EC and moisture content evolution in T1 and T2. Watering of piles (full symbols) and rainfall days (empty symbols) are indicated.

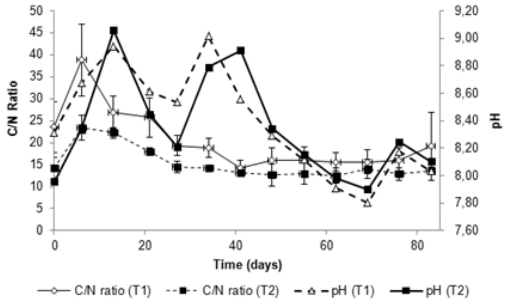
Fig. 3 a) OM loss (%) and SRI (mg O_2 g^{-1} OM h^{-1}); **b)** SOC (%) and LEA (EU) evolution in T1 and T2

Fig. 4 N losses (%) and NH_4^+ concentration (mg g^{-1}) evolution in T1 and T2

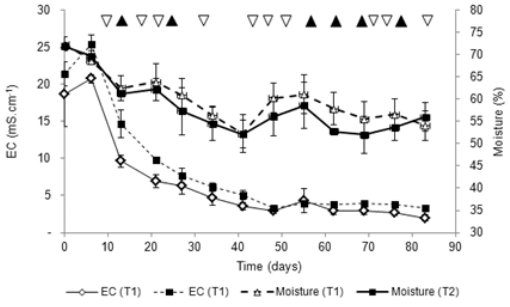
Fig. 5 Principal component analyses of parameters determined in the final composts. 1, 2 and 3 dots belong to the replicates of T1, 4, 5 and 6 dots belong to T2

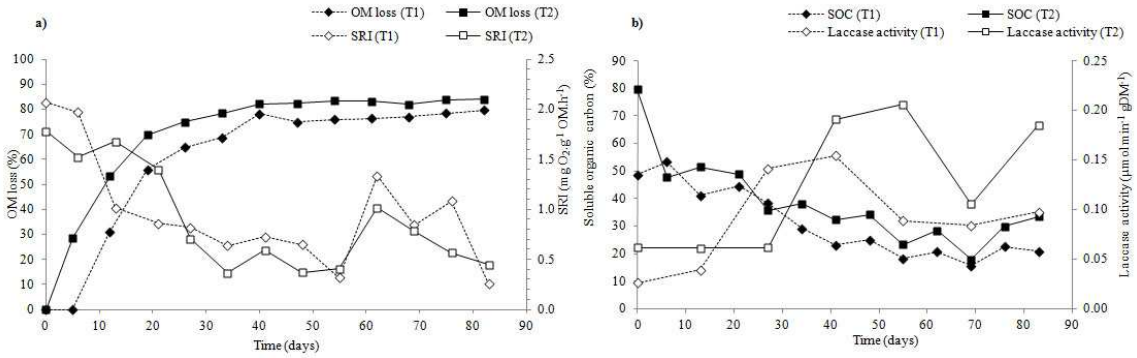

T1
T2
Environmental average temperature
Temperature (℃)
Time (days)
0
10
20
30
40
50
60
70
80

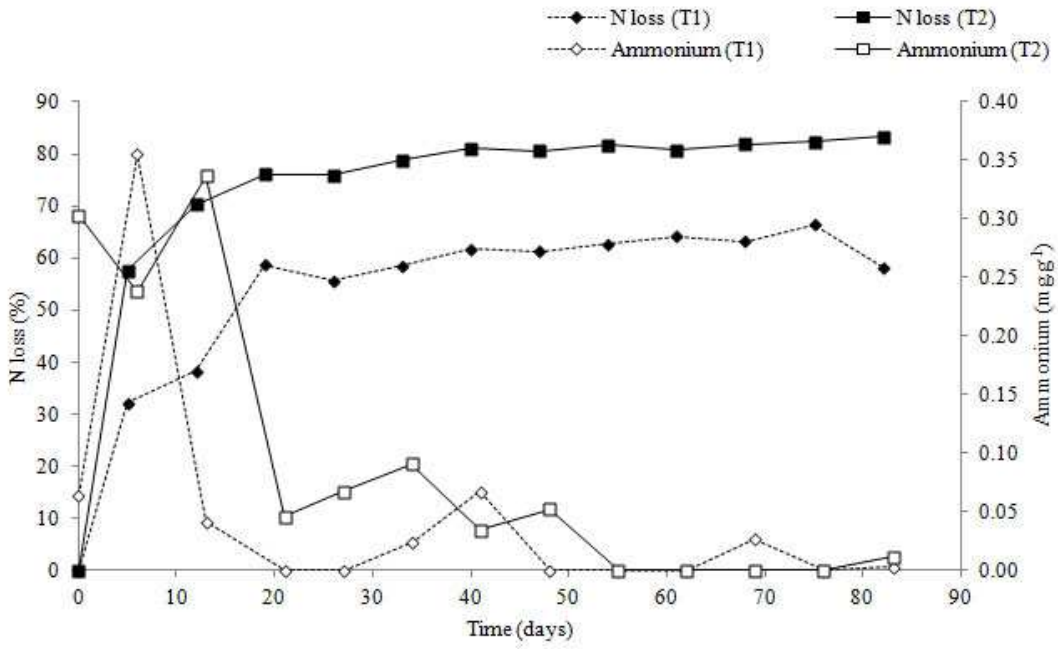
a)

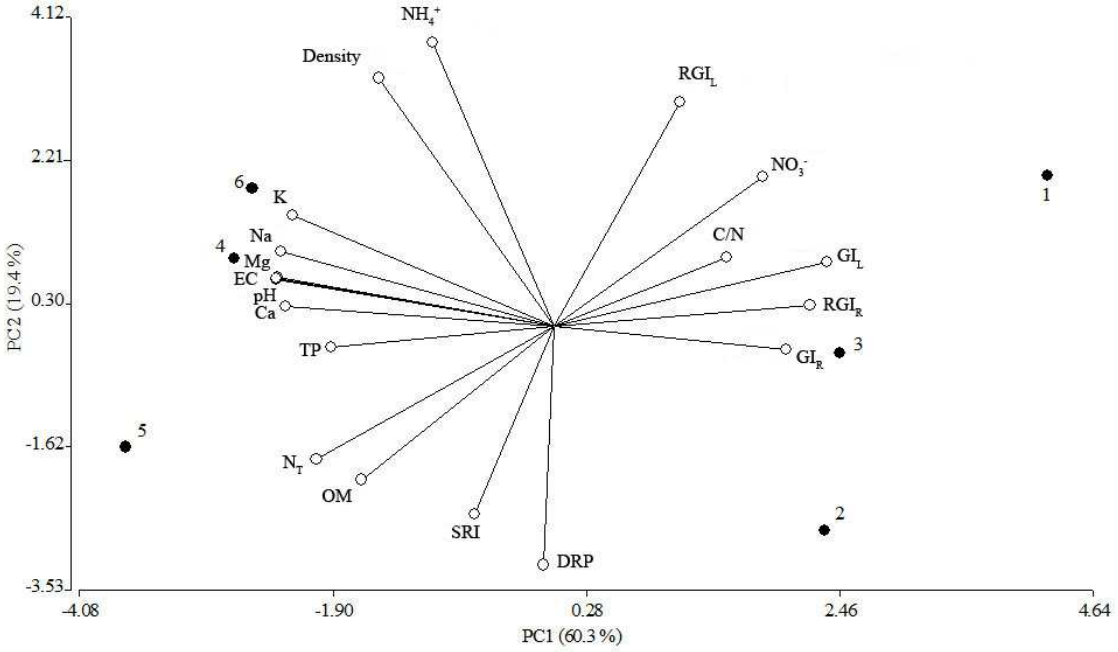

C/N Ratio
pH
Time (days)
C/N ratio (T1)
C/N ratio (T2)
pH (T1)
pH (T2)

b)


EC (mS.cm-1)
Moisture (%)
Time (days)
EC (T1)
EC (T1)
Moisture (T1)
Moisture (T2)


a)
OM loss (T1)
OM loss (T2)
SRI (T1)
SRI (T2)
OM loss (%)
SRI (mg O_2 g^{-1} OM h^{-1})
Time (days)
b)
SOC (T1)
SOC (T2)
Laccase activity (T1)
Laccase activity (T2)
Soluble organic carbon (%)
Laccase activity (µmol ml min^{-1} gDM $^{-1}$)
Time (days)


N loss (T1)
N loss (T2)
Ammonium (T1)
Ammonium (T2)
N loss (%)
Ammonium (mg g-1)
Time (days)
0
10
20
30
40
50
60
70
80
90
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


4.12
2.21
0.30
-1.62
-3.53
PC2 (19.4 %)
-4.08
-1.90
0.28
2.46
4.64
PC1 (60.3 %)
NH4+
Density
RGIL
NO3-
C/N
GIL
RGIR
GIR
TP
NT
OM
SRI
DRP
K
Na
Mg
EC
pH
Ca
1
2
3
4
5
6