RECYCLING OF DIGESTATES FROM BIOGAS PRODUCTION BY COMPOSTING

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1 INTRODUCTION

Intensification of livestock production has led to a generation of great amounts of animal manures and slurries that can constitute a potential environmental risk, if their management is not optimised. Anaerobic digestion constitutes one of the main alternatives to manage these wastes and is based on the anaerobic conversion of organic matter, obtaining biogas and a digested substrate called digestate. Although digestate presents a high fertilising value, this material shows some characteristics, such as its phytotoxicity, which advices against its use as soil amendment in its basic form. Therefore, composting can constitute a suitable treatment to stabilise digestate and thus, to improve its properties prior to its use as soil conditioner. However, the solid-liquid separation usually implies the addition of co-adjuvants, such as PAM (Polyacrylamide derivate) which could induce disturbances in composting. The objective of this work was twofold: i) to study the evolution of the composting process of the solid phase of digestates obtained from the anaerobic digestion of pig slurry (PSD) and wastes from the agricultural activity (wheat straw (WS), vine shoot pruning (VP) and pepper plant pruning (PP)) and from the agro-food sector (exhausted grape marc (EGM)) and ii) to evaluate the characteristics of the end-products obtained.

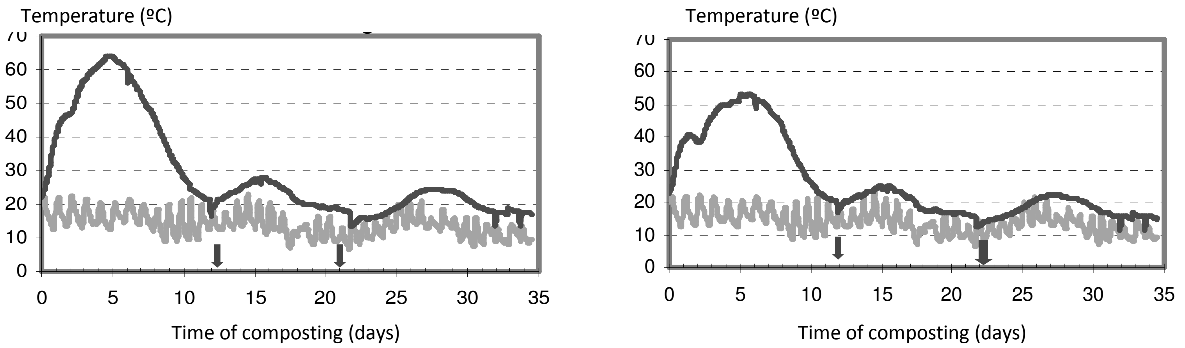
2 MATERIALS AND METHODS

Pig slurry digestate (PSD) was obtained from a centralized treatment plant of pig slurries in Catalonia using thermophilic anaerobic digestion. The solid phase of this digestate was separated by centrifugation and used in the pile elaboration without any additional preparation procedure. To carry out our objectives, five mixtures were composted in 350 L thermo-composters by the turning composting system. These mixtures (P1, P2, P3, P4 and P5) were established mixing in all of them the solid phase of PSD with WS (P1 and P2), with EGM (P3), with VP (P4) and with PP (P5). In all the scenarios, 70-75% of PSD was used, in terms of dry matter content. In addition, P2 was watered with the liquid phase of the anaerobic digestate of pig slurry (LPS); 0.22 L LPS per kg was added on the first day and the remaining volume, up to 0.45 L kg^{-1} was added gradually up to 27 days of composting, while the rest of piles were watered with water, maintaining a moisture content higher than 40 %. When the bio-oxidative phase of composting was considered finished, composts were left to mature for a month, approximately. Throughout the composting process, physico-chemical, chemical and biological parameters were studied. In mature compost, composition and quality assessment were made.

3 RESULTS AND DISCUSSION

3.1 Composting process

In general, thermophilic temperature was reached in the first week of the composting process, showing piles P1, P2, P4 and P5 the highest temperature values (Figure 1). All piles reached 50ºC except P3, which did not reach thermophilic conditions throughout all the experiment. Each pile was turned between 1 (piles 4 & 5) and 2 times (piles 1 to 3). These piles did not reach the temperature requirement established by the 2nd Draft on Biological Treatment of Biowastes (EC, 2001), mainly due to the composting scale used, only showing piles P1 and P4 the most exothermic behaviour with ceiling temperatures closer or higher than 60ºC. However, sanitization standards were achieved in almost all the composting piles (except pile 4).



Pile P1: solid phase of pig digestate + wheat straw (Humidity source: water)

Pile P2: solid phase of pig digestate + wheat straw (Humidity source: digestate)

FIGURE 1 **Thermal profile of composting piles P1 and P2 (bottom lines are ambient temperature).**

Losses of OM were calculated from ash contents according to the equations of Paredes et al. (2000). A first-order kinetic model was used for OM degradation during composting (Bernal et al., 1996). This model was chosen as the best fit because it gave a randomised distribution of the residuals together with the lowest residual mean square (RMS) value (data not shown) and a highly-significant F-value. The equation used was: OM loss (%) = A $(1 - e^{-kt})$ where A is the maximum degradation of OM (%C), k the rate constant (d^{-1}) and t the composting time (d). The highest organic matter degradation was observed in P1, which showed the greatest temperature values. However, the thermal profile and the losses of organic matter were lower compared to other composting processes (Bernal et al., 1996) using solid phases of pig slurries, probably due to the specific nature of our PSD and the use of PAM in its separation process. At the end of the composting process, all composts had a C/N ratio < 20 and a total absence of phytotoxicity (GI > 50%), which revealed the stabilisation of the organic matter in the mixtures studied.

TABLE 1 **Modelization of organic matter losses during composting**

	Pile 1	**Pile 2**	**Pile 3**	**Pile 4**	**Pile 5**
A	34.52 (11.00)	25.61 (1.51)	6.27 (1.35)	12.91 (1.04)	16.30 (5.34)
k	0.0397 (0.0265)	0.1740 (0.0516)	0.0620 (0.0363)	0.1046 (0.0313)	0.0313 (0.0214)
Adjusted r^2	0.5269	0.9198	0.7547	0.9162	0.8731
F-value	7.68^{*}	69.82^{***}	16.38^{*}	55.68^{**}	28.53^{*}
Estimation standard error	7.4312	2.7847	1.3037	1.4451	2.0835

3.2 Compost agronomic composition and quality assessment

The main agronomic characteristics of the composts are shown in Table 2. These composts showed a recalcitrant humidity, this aspect being especially important if the material is not allowed to mature. At the end of the composting process, all the composts showed pH values near to neutrality, and electrical conductivity (EC) values higher than 5 dS/m, probably due to the great content of salts of PSD. The use of wheat straw in the mixtures (P1 and P2) induced significantly higher salinity than other co-composting agents, such as vine shoot or pepper plant pruning. The addition of digestate (P2) did not significantly increase EC compared to water (P1).

The final levels of organic matter, total organic carbon and total nitrogen were higher o similar to those observed in other composts (Ranalli et al., 2001). Organic matter contents were higher than the minimum values established by the Spanish and the European legislation (35% and 30%, respectively) (BOE, 2005; EC, 2001). Also, total nitrogen contents were greater than 2.75% in all the investigated composts. With respect to phosphorus and potassium, compost values ranged between 26 and 34 g/kg, and 9.8 and 15 g/kg respectively. These fertilising contents varied depending on the mixtures, without any effect of the digestate use on these elements.

TABLE 2 **Agronomic characterization of the digestate derived-composts**

Parameter	**P1**	**P2**	**P3**	**P4**	**P5**
Dry matter (%)	33.8	28.9	34.6	37.1	43.2
pH	6.42	6.94	6.52	6.53	6.63
Electrical conductivity (dS/m)	8.88	8.08	5.34	5.11	6.79
Total organic matter (%)	71.0	72.5	67.0	67.6	59.6
Total organic C (%)	35.0	36.2	33.0	34.5	30.3
Total N (%)	2.75	2.94	3.13	3.03	3.32
P (g/kg)	30.9	26.4	37.8	33.7	34.2
K (g/kg)	15.1	10.8	11.5	9.78	13.8
Ca (g/kg)	28.0	25.7	62.9	59.9	58.9
Mg (g/kg)	19.8	19.1	34.0	30.8	30.5
Na (mg/kg)	466	346	3475	3517	3639
Fe (g/kg)	5.94	5.93	9.65	9.09	9.79
Mn (mg/kg)	530	519	1020	904	860
Cu (mg/kg)	333	332	556	518	486
Zn (mg/kg)	1779	1730	3052	2776	2534

Cu and Zn contents are usually high in pig slurries and composting increased their concentration. In our composts, Zn could be the limiting element to use the compost, according to the Spanish legislation. However, Fe was significantly high in all the compost, probably due to the use of iron salts in the separation phase procedure of PSD. Multiresidual pesticide analyses were developed for mature composts without any value over detection limits of GC-MS technique. In terms of pathogens, only P2 and P4 showed any incidence (*E. coli* > 1000 NMP/g and *Salmonella* spp. presence, respectively).

The values of the parameters considered to ascertain the maturity and stability of the obtained composts, as well as the limit values suggested by different authors to consider that a compost is stable and mature are displayed in Table 3. Comparing the values obtained for the composts P1, P2, P3, P4 and P5, it can be observed that all the composts verify more than 62% of the maturity criteria, P1 being the compost that verifies the highest percentage, with 81.3% of the stability and/or maturity criteria. Other parameters, associated to compost use as organic amendment in agricultural soils, such as the C/N ratio, CEC or CEC/Ct, also verify the values established by other authors (Table 3).

TABLE 3 **Stability and/or maturity indices for the digestate derived-composts**

Parámeter	**Quality index**	**Source**	**P1**	**P2**	**P3**	**P4**	**P5**
WSC (%)	**< 0.5**	García et al. (1992)	1.54	1.33	0.90	0.81	0.58
	< 1	Hue and Liu (1995)	1.54	1.33	**0.90**	**0.81**	**0.58**
	< 1.7	Bernal et al. (1998)	**1.54**	**1.33**	**0.90**	**0.81**	**0.58**
Ct/Nt	**< 20**	Golueke (1981)	**12.7**	**12.3**	**10.5**	**11.4**	**9.12**
	< 15	Juste (1980)	**12.7**	**12.3**	**10.5**	**11.4**	**9.12**
HR[2] (%)	**> 7**	Roletto et al. (1985)	**39.0**	**13.7**	**8.6**	**9.3**	**10.6**
HR[3] (%)	**> 3.5**	Roletto et al. (1985)	**32.1**	**6.7**	2.9	**3.9**	**4.8**
	> 13 %[a]	Iglesias-Jiménez et al. (1992b)	**630**	**147**	**33**	-7.3	9.9
Pah[4] (%)	**> 62 %[a]**	Iglesias-Jiménez et al. (1992b)	**104**	**109**	23.6	24.0	11.9
Cah/Caf[5]	**> 1**	Roletto et al. (1985)	**9.63**	0.98	0.50	0.72	0.83
	Δ > 1.6[a]	Iglesias-Jiménez et al. (1992b)	**3.96**	0.67	0.13	0.20	0.16
GI[6] (%)	**>50**	Zucconi et al. (1981)	**97.9**	**82.9**	**66.2**	**79.8**	**77.4**
CEC[7]	**> 60**	Harada and Inoko (1980)	**131**	**132**	**176**	**171**	**170**
(meq/100 g MO)	**> 67**	Iglesias-Jiménez et al. (1992b)	**131**	**132**	**176**	**171**	**170**
CEC/Ct	**> 1.9**	Iglesias-Jiménez et al. (1992a)	**2.67**	**2.64**	**3.59**	**3.36**	**3.36**
(meq/g Cot)	**> 3.5**	García et al. (1992)	2.67	2.64	**3.59**	3.36	3.36

[1]WSC: water-soluble organic C; [2]HR: humification ratio; [3]HI: humification index; [4]Pah: percentage of humic acids; [5]PR: polimerization ratio, where C_{ha}: humic acid-like carbon; C_{fa}: fulvic acid-like carbon; [6]GI: germination index; [7]CEC: cation exchange capacity. [a]The values shown in this row are increments (final value – initial value).

4 CONCLUSIONS

Composting of the solid phase of digestate (PSD) from pig slurries could be a feasible form to manage this residual flux. In our experiment, the thermal profile and the losses of organic matter were lower compared to other composting processes using solid phases of pig slurries, probably due to the digestion procedure, using PAM in the separation process, which produces a PSD with a specific nature. So, the selection of the co-composting agents is crucial in order to optimise the process and also to improve the composition and quality of the final compost. Electrical conductivity and Zn were the most limiting factors for the use of our composts in agriculture. Scaling the proposed composting processes must be developed in order to check the accomplishment of the stabilisation and quality patterns of the proposed mixtures.

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