Monitoring and evaluation of composting as manure management strategy in the Region of Murcia (Spain)

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Abstract
The intensive and concentrated activity of the pig farms generates vast amounts of biodegradable wastes that must be managed under appropriate disposal practices to avoid any negative impact on the environment. Composting has been considered a suitable option for manure management in the agriculture. So, the objectives of this work were to establish the technical requirements for pig slurry composting and to determine the feasibility of this method as an alternative management strategy for recycling pig manure in an important pig production region of Spain. For this, a composting trial using the solid phase of pig slurry was set up in a farm located in the highest slurry production area in the Region of Murcia (Spain). The results obtained have shown that composting of the solid phase of pig manure can be an efficient treatment to recycle this type of wastes, but it can show some constraints, such as the high Zn concentrations in the final compost that can limit compost quality.

Introduction
The intensification of the livestock production systems, especially of the pig production sector, has resulted in a high density of animals in relatively small areas that produces large quantities of wastes [1]. In the EU-27, with more than $13{\times}10^6$ of pig livestock units, approximately $295{\times}10^6$ tons of pig manure are produced every year. This intensive livestock production can suppose a potential environmental impact, if the manure is not properly managed [2]. In this sense, the objective of the EU LIFE+ Project MANEV "*Evaluation of manure management and treatment technology for environmental protection and sustainable livestock farming in Europe*" is to demonstrate that both the use of treatment technology and an environmentally correct management scheme of pig manure can contribute to improve environmental protection, with a reduction of GHG emissions, and the sustainability of livestock industry. For that several technologies for manure management are being monitored across Europe, and particularly composting is being tested in Murcia (Spain), one of the most highly concentrated pig production areas of Spain. This is carried out by a common evaluation and monitoring protocol for all the different European zones. Afterwards, with all the data obtained, a Life Cycle Assessment (LCA) of every scheme will be created, which includes the three pollution potentials: global warning; eutrophication; acidification, energy balancing and economic aspects. Therefore, the main aims of this study were to establish the technical requirements for pig slurry composting and to determine the viability of this method as an alternative management strategy for the recycling of pig manure in the studied area.

Materials and Methods
Experimental procedure
A farm equipped with a screw press for solid-liquid pig slurry separation system (mechanical separator without flocculants) was selected for the pig slurry composting study. This was a sows and piglets farm with the following infrastructure for managing the pig slurry: a pig slurry storage tank with aerobic pre-treatment, a screw press, a system for aerobic treatment of the liquid fraction in a tank, and a solid-surface area next to the separator for storage of the solids and the composting pile, with the adequate slope for leaching collection to the storage tank. A composting pile was established with the solid fraction of separated slurry, using the cereal straw available in the farm as bulking agent (volume ratio 2:1). The mixture was prepared in a trapezoidal pile (approximately 4.8 m^3) and composted by the turning composting system. The pile was turned three times when the temperature started to decrease to improve both the homogeneity of the materials and the composting process. Additionally, 30L of fresh pig slurry were incorporated to the mixture at the time of the second turning, in order to provide easily degradable organic matter and a source of microorganisms. Throughout the composting process, the moisture of the pile was adjusted to 60 % in order to avoid leaching and the temperature

evolution was monitored. The bio-oxidative phase of composting was considered finished when the temperature of the pile was close to the ambient and re-heating did not occur after turning. Then, the compost was left to mature over a period of one month. The samples were taken by mixing seven subsamples from seven representative sites of the pile, from the whole profile (from the top to bottom of the pile). Each representative sample was divided into three fractions in the laboratory: one of them was dried in a drying-oven at 105 ºC for 24 h to determine the moisture content, the second was immediately frozen (-18 ºC) and kept for the determination of NH_4^+-N and pathogenic microorganisms, and the third was air-dried and ground to less than 0.5 mm for the rest of the analytical determinations.

Analytical methods

In the initial materials and in the composting samples, electrical conductivity (EC) and pH were analysed in a 1:10 (w/v) water-soluble extract. Total organic C (C_T) and total N (N_T) were determined by automatic microanalysis. Organic matter (OM) was assessed by loss-on ignition at 500 °C for 24 h. After HNO_3/$HClO_4$ digestion, nutrients and heavy metals were measured by ICP-OES. Pathogenic microorganisms (*E. coli* and *Salmonella*) were determined in the initial mixture and the mature compost. The germination index (GI) was calculated using seeds of *Lepidium sativum* L. All the analyses were made in triplicate and according to standard methods.

Results and discussion

Development of the composting process

The evolution of the temperature in the composting pile showed an initial slow development of the composting process, requiring 3 weeks to reach thermophilic values (Fig. 1a). Probably the aerobic pre-treatment carried out on the pig slurry before solid-liquid separation, partially degraded the labile organic matter of pig slurry. However, the incorporation of fresh pig slurry into the mixture produced an activation of the process, reaching from then temperatures higher than 55ºC for 14 days, which ensured the maximum pathogen reduction according to the European guidelines on compost sanitation [3]. In fact, the pathogenic microorganisms decreased during the process, *E.coli* from 5 10^5 to not detect; total coliforms from 5.6 10^3 to 7.6 10^1; and *Salmonella* was absent in 25 g dm. After 56 days of composting, the temperatures progressively fell to reach the ambient values, the bio-oxidative phase of composting lasting 75 days and the whole process, 170 days. The mass balance (Fig. 1b) showed a decrease in the moisture contents and in the OM concentrations, this decrease being more remarkable in the early stages of the composting process, due to the highest microbial activity shown by the high temperature values reached in the pile [3].

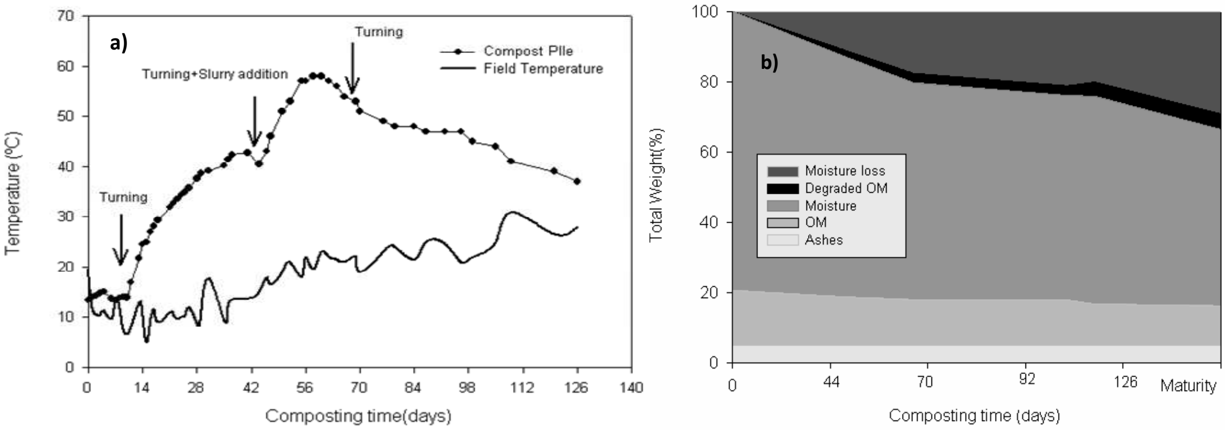

Figure 1. a) Temperature profile of the composting pile (arrows indicate turnings); b) Mass balance during the composting process.

The evolution of the physico-chemical and chemical parameters in the mixture during composting indicated a good development of the process (Table 1). During composting, pH values decreased from slightly alkaline values, probably due to the generation of acid-type organic compounds of low molecular-weight from the decomposition of the most-easily-degradable OM fraction [3], reaching values close to neutrality in the final compost. OM degradation produced an increase in EC in the mixture (Table 1), due to the mineralisation process leading to inorganic compounds and the increasing relative concentration of ions due to the mass loss of the pile [3]. The final EC value was lower than 5 dS/m.

Table 1. Evolution of some physico-chemical, chemical and biological parameters during composting (dry weight basis).

Composting time (days)	pH	EC (dS/m)	C_T (%)	N_T (%)	C_T/N_T	NH_4^+-N (mg/kg)	NO_3^--N (mg/kg)
0	8.22	2.02	35.4	2.43	14.6	8655	1181
44	8.54	1.70	35.3	2.69	13.1	3941	n.d.
70	7.98	2.11	30.6	2.48	12.3	1825	2116
92	7.93	2.50	26.1	1.74	15.0	1299	2705
126	6.60	3.41	27.0	1.82	14.8	118	n.d.
170	6.47	4.52	25.0	2.65	9.4	58	5466

EC: electrical conductivity; C_T: total organic carbon; N_T: total nitrogen; GI: germination index; n.d.: not determined.

The C_T concentration decreased with composting time showing the degradation of the OM. N concentrations increase during composting, reaching at the end of the process a value > 2% in the final compost. The C/N ratio decreased, especially at the beginning of the process when the OM degradation was at the greatest, and then stabilised, reaching values <12 thereafter, the limit established by different authors as the limit for mature compost [3]. A great decrease in the NH_4^+-N concentration was observed in the pile, mostly due to volatilisation and nitrification processes, the latter being especially notable at the end of the process when a notable increase in nitrates was observed. The final NH_4^+-N reached in the pile was lower than 400 mg/kg, the maximum value recommended value for a mature compost [3]. The GI clearly increased in the pile throughout composting, from no germination in the initial mixture to 87.8 % in the final compost, greater than 50%, the limit value that indicates absence of phytotoxins [3]. In general, heavy metal concentrations were lower than the limits established for compost by the European guidelines [4] (data not shown), except for Zn (5445 mg/kg), due to the high concentration of this metal found in the pig slurry, mainly from piglets.

Monitoring protocol and LCA

In order to obtain comparable results between the technologies from the different partners, a common monitoring protocol was developed for all partners of the MANEV project. Such protocol specifies the parameters, evaluation procedure and functional units for all technologies, in order to develop the LCA. The parameters to be tested include those describing the environmental impact of the technologies, such as: air pollution (acidification by NH_3 and SO_2 emissions); water pollution (eutrophication by total-N and total-P); and climate change (GHP by CO_2, CH_4, N_2O emissions and CO_2 savings). The monitoring period is fixed in a natural year, and the functional unit is m^3 of slurry, which can be transformed into weight. Standard default emission factors specified by different organisms [5, 6] will be compared with those obtained from the experimental results, as they may be influenced by the climatic conditions.

Every technology has its own sampling protocol and boundaries. In the case of the composting system established in a farm in Murcia, three steps are defined: storage and pre-treatment (aeration and separation); treatment (composting); end products (compost and irrigation water). The starting point for the evaluation is the storage tank, and the end point corresponds to the end products obtained for land use. In order to obtain comparable results, the sampling points and emissions monitoring throughout the evaluation period will be always taken from the same points in the process line (Fig. 2).

From the point of view of composting the potential GHG debits and credits can be split into three categories: 1- the CH_4 generation potential of compost feedstocks; 2- the composting process, including energy use and emissions during composting; and 3- the end use of compost. In the first case, the C credits associated to composting of pig slurry are through CH_4 avoidance when slurry is composted instead of stored in a lagoon. During composting, the CO_2 emission is not considered as an additional GHG emission since feedstocks are part of the short-term C-cycle [7]. However, CH_4 and N_2O should be considered as potential GHG. The C/N ratio of the material, moisture, and composting aeration system are affecting such emissions. With respect to the end use of the compost, the potential credits can be associated to the beneficial effect of compost on soil fertility: increased soil water holding capacity (reduced irrigation water), nutrient supply (reduction of synthetic fertilisers), herbicide reduction, and C-sequestration. Also the substitution of peat by compost in horticulture can be accounted for C credits.

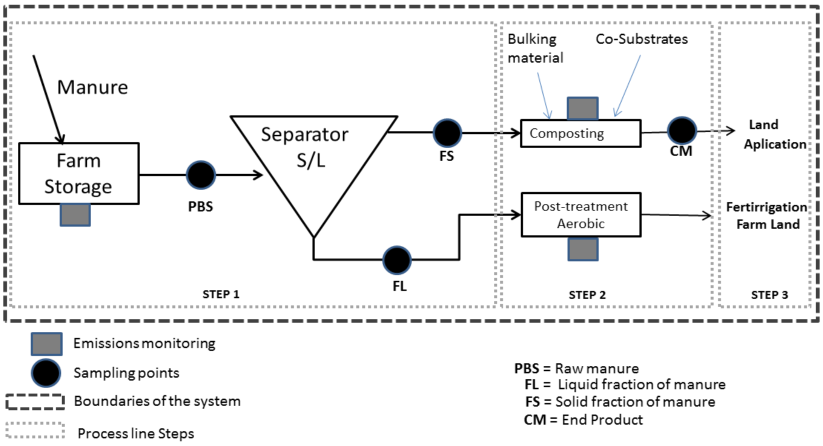

Figure 2. Process line and sampling protocol in the farm

Conclusion and perspectives

Composting can be considered a feasible technology for pig slurry management in areas where direct soil application for recycling of nutrients in the soil-plant system is not possible, or where there is an excess of manure produced for the nutrient crop requirements.However, the composting of the solid phase of pig manure can show some constraints, such as limited temperature development and high Zn concentration which can limit compost quality. For this reason the optimisation of the composting of pig slurry will include the use of another bulking agent, such as cotton waste which has demonstrated in laboratory experiments to quickly increase the temperature of the composting mass, and the use of the solid fraction of pig slurry from sows, with reduced Zn content.
The monitoring of the composting system at the farm is currently taking place. Direct measurements of gas emissions will be carried out in the scenario and the results will contribute to the LCA to be developed at the MANEV project, for developing a decision making tool.

References

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