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Research article

Evaluation of the slurry management strategy and the integration of the composting technology in a pig farm – Agronomical and environmental implications

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ABSTRACT

The changes in livestock production systems towards intensification frequently lead to an excess of manure generation with respect to the agricultural land available for its soil application. However, treatment technologies can help in the management of manures, especially in N-surplus areas. An integrated slurry treatment system based on solid-liquid separation, aerobic treatment of the liquid and composting the solid fraction was evaluated in a pig farm (sows and piglets) in the South of Spain. Solid fraction separation using a filter band connected to a screw press had low efficiency (38%), which was greatly improved incorporating a rotatory sieve (61%). The depuration system was very efficient for the liquid, with total removal of 84% total solids, 87% volatile solids, and 98% phosphorus. Two composting systems were tested through mechanical turning of: 1- a mixture of solid fraction stored for 1 month after solid-liquid separation and cereal straw; 2- recently-separated solid fraction mixed with cotton gin waste. System 2 was recommended for the farm, as it exhibited a fast temperature rise and a long thermophilic phase to ensure compost sanitisation, and high recovery of nutrients (TN 77%, P and K > 85%) and organic matter (45%). The composts obtained were mature, stable and showed a high degree of humification of their organic matter, absence of phytotoxicity and concentrations of nutrients similar to other composts from pig manure or separated slurry solids. However, the introduction of slurry from piglets into the solid-liquid separation system should be avoided in order to reduce the content of Zn in the compost, which lowers its quality. The slurry separation followed by composting of the solid fraction using a passive windrow system, and aeration of the liquid phase, was the most recommendable procedure for the reduction of GHG emissions on the farm.

1. Introduction

According to the FAO (FAO, 2009), growing demand for livestock products has led to widespread changes in livestock production systems; there has been a rapid growth in the average size of primary production units and a shift towards fewer and larger farms in many parts of the world. One major reason for this is that larger operations are better placed to benefit from technical advances and economies of scale, such as those embodied in improved genetics, compound feeds or improved organisation, especially in poultry and pig production (FAO, 2009). This implies that slurry production is highly concentrated in some areas, at both national and local scales, which frequently leads to an excess of manure with respect to the agricultural land available for its soil application.

Within the EU, Spain has the second-greatest number of pigs (26.6 million heads in 2014), after Germany (28.3 million heads), this meaning 18 and 19% of the total pig heads in the EU, respectively (FAOSTAT; http://faostat3.fao.org/). Although the use of pig slurry in agricultural soils is considered the best management option, some limitations exist - especially in areas vulnerable to

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nitrate pollution, where the annual N application in the form of animal manures is limited to 170 kg N ha^{-1}. The excess slurry produced could be transported to N-deficient agricultural areas, but this strategy has environmental and health risks associated as well as an economic cost that is frequently not affordable considering the nutrients supplied by the pig slurry. Solid-liquid separation technology requires the management of both solid and liquid fractions independently (Hjorth et al., 2010); nutrients and organic matter are concentrated in the solid fraction, which can be managed as a solid manure or transported to other areas at lower cost, while the liquid fraction is rich in N (mainly NH_4^+) and K, which can be managed in agriculture or treated for nutrient removal (Riaño and García-González, 2014).

Treatment technologies can play a role in the management of manures in N-surplus areas. The different technologies can recover energy from livestock manures, make them more stable and/or remove or concentrate nutrients from the main stream, all of which change the characteristics of the manure (Foged et al., 2011). These techniques can be considered as greenhouse gas (GHG) mitigation strategies, as they can achieve efficient recycling of waste products while reducing the potential spread of pollutants, and solve specific problems such as malodours, ammonia emissions, storage capacity at the farm level or safe transfer of nutrients from manure (Martinez et al., 2008; Peigne and Giudin, 2004). The managing of the manure is considered the major source of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions in pig farms, and different mitigation strategies have been suggested in this regard (Jiang et al., 2011; Pardo et al., 2015; Sommer et al., 2013).

Composting has been proposed as a practical and economical way of recycling animal manures at the farm and community levels (Bernal et al., 2009; Martinez et al., 2008; Nolan et al., 2011). Through composting, the manure or slurry can be transformed into organic fertiliser, reducing the volume, odour and moisture content and also contributing to the elimination of pathogenic microorganisms, allowing the safe transfer of the excess manure nutrients to other agricultural areas (Bernal et al., 2009; Onwosi et al., 2017). However, the liquid nature of pig slurry - which has high moisture content (dry matter 2.27%; Moral et al., 2008) - and its high total-N (TN) (mainly as NH_4^+-N) content with respect to the total organic C (TOC) (Sánchez and González, 2005) are not adequate for its composting (Bernal et al., 2009; Troy et al., 2012). Pig slurry pretreatment by a solid-liquid separation system is required for concentration of the solids (Jorgensen and Jensen, 2009), while the addition of a bulking agent may adjust the C/N ratio, regulate the excess water content in the solid fraction and provide adequate porosity and aeration for composting (Santos et al., 2016; Troy et al., 2012). The bulking agent should also be easily available to the farm, without significant economic cost, to ensure the viability of the treatment system. For that reason, bulking agents are usually lignocellulosic waste materials or by-products, typically from agriculture or forestry, such as cereal straw (Barrington et al., 2002), wood shavings (Ros et al., 2005; Ko et al., 2008), sawdust (Troy et al., 2012), corn stalks (Guo et al., 2012), rice straw (Qian et al., 2014) and cotton gin waste (Vanotti et al., 2006).

The choice of the bulking agent may influence the development of the composting process and the quality of the end-product (Onwosi et al., 2017). Adjusting the C/N ratio with a bulking agent in composting has been found to be useful for controlling CH_4, CO_2 or N_2O emissions (Yamulki, 2006). Pardo et al. (2015), using a meta-analysis approach in solid composting, indicated that improving the structure of the pile by controlling the bulking agent significantly reduced N_2O and CH_4 emissions (by 53% and 71%, respectively), while turned composting systems showed potential for reducing GHGs in comparison with static pile systems (N_2O (50%) and CH_4 (71%)). Some approaches at the farm scale have been developed in order to mitigate the GHG emissions (del Prado et al., 2013). This is considered the most-appropriate scale at which mitigation options can be evaluated, because the farm represents the unit at which management decisions in livestock production are made.

Therefore, the aim of this study was to determine the efficiency of the slurry treatment system and the composting as a strategy for the treatment of the solid fraction of pig slurry. Agronomic aspects and the environmental impact concerning the greenhouse gas (GHG) emissions of the slurry management system of a pig farm were also evaluated. The starting hypothesis was that including composting of solids into the existing slurry treatment system of the farm can improve the quality of the separated solid material - dryness, microbial stability, concentration of nutrients, OM humification and sanitisation - for its exportation outside the farm while reducing the environmental impact of the process. The starting point for the evaluation of the treatment system was the storage tank; therefore, considerations regarding the type and conditions of animal houses are out of the scope of this article.

2. Materials and methods

2.1. Pig slurry treatment system of the farm

The study was carried out on a sows and piglets farm, with a capacity for 500 sows and an annual production of 1500 piglets, located within the municipality of Cuevas de Almanzora (Almería, Spain), with 1.57 ha of citrus trees (lemons, oranges, mandarins and grapefruits). The farm was equipped with a pig slurry treatment system based on a slurry storage tank, mechanical separation of the slurry, a tank for aerobic treatment of the liquid fraction and a solid-surface area for storage and composting of the solid fraction (Fig. S1, Supplementary Material). Raw pig slurry (from both sows and piglets) collected from slatted-floor houses was pumped to an open storage tank, which was the starting point for the evaluation of the treatment system.

From the storage tank, slurry was pumped to the solid-liquid mechanical separation system, which comprises three steps

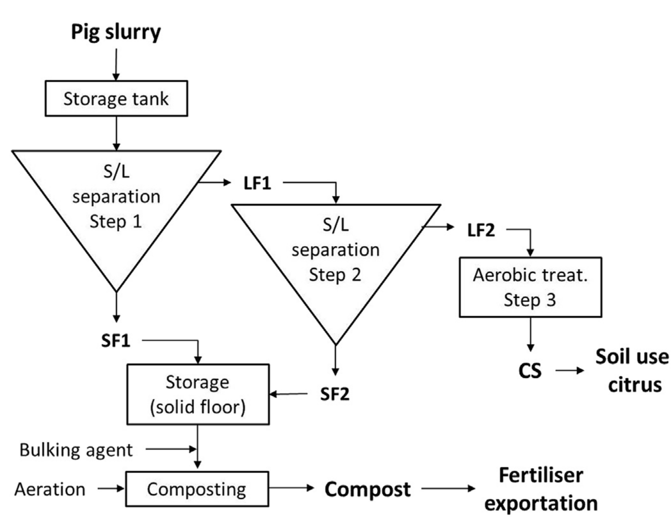

Fig. 1. Scheme of the pig slurry treatment system of the farm: pig slurry was stored in a tank and pumped to the solid-liquid mechanical separation system: step 1) a filter band (0.65 mm pore size) connected to a screw press (giving fractions SF1 and LF1); step 2) the liquid fraction obtained from 1 (LF1) is then pumped to a rotatory sieve (0.20 mm pore size) (giving SF2 and LF2); and step 3) the liquid fraction (LF2) is treated with intermittent aeration in a tank, obtaining a clarified supernatant (CS) for fertilisation of citrus crops on the farm. Both solid fractions (SF1 and SF2) were stored together for composting, with the production of a compost which can be used as a fertiliser and/or exported from the farm.