Agronomical and environmental implications of on-farm slurry management based on two-step separation and acidification treatment

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In the EU-27 alone, 1,500 million tonnes of manure are produced annually, generating 78% of Europe's NH_3 emissions (Holm-Nielsen et al., 2009). The livestock sector is responsible for 14% of greenhouse gas (GHG) emissions and 64% of NH_3 emissions worldwide. In many cases, national and European legislation sets limits to the amount of manure utilized as organic fertilizer while the quantities of animal manures produced in concentrated areas of intensive livestock production has risen (Hjorth et al., 2010). The excess amount of animal manure still represents a significant nutrient and organic matter capital that can minimise food producers' dependency on mineral fertilisers and sustain soil quality (Holm-Nielsen et al., 2009). Nevertheless, excessive application of manure can lead to nitrate (NO_3) and phosphorus (P) leaching to surface water and groundwater, resulting in recued water quality as well as a loss of valuable nutrients from the agricultural system (Sørensen and Jensen, 2013).

Mechanical separation of animal slurries has been adopted, by mostly centralized farms, to promote an efficient and environmental friendly nutrient recycling within the farm and a more feasible redistribution of nutrients between farms (Jensen, 2013). The liquid fraction of the slurry can be used as an easily accessible plant N-K fertilizer between closely located farms. The more concentrated solid fraction, can be transported to greater distances compared to the liquid fraction (Foged et al., 2012). It contains the majority of the manure's P, most of the organic matter and organic N, as well as a relatively high content of mineral N (Peters et al., 2011). Nevertheless, the distribution of moisture, organic matter, nutrient content and fertilizing value between the resulting liquid and solid fractions after mechanical separation largely depend on the type and operating conditions of the mechanical separator. Available data on the effect of the separator's operational conditions on the nutrient content of the resulting fractions are largely obtained in laboratory conditions and experimentation on large scale conditions is generally lacking.

Therefore, the objectives of this study were to determine the efficiency of a two-step swine slurry separation system and the integration of acidification as a strategy for treatment of the liquid effluent. Agronomic aspects related to the fertilizing value of the on-farm produced fractions and the greenhouse gases (GHG) emissions of the slurry management system were also evaluated.

The study was carried out on a pig farm with the capacity to have 30,000 animals at different growing stages, located in Poland. The slurry management on the farm consists of a two-stage mechanical separation of the slurry, where the first consists of a screw press while the liquid effluent is further treated in a decanted centrifuge. The liquid effluent after centrifugation of the slurry is acidified with concentrated sulfuric acid and stored at a lagoon covered with floating plastic. Moreover, the manure solids produced are transported to a near-by anaerobic digestion plant.

To monitor the system's efficiency to separate nutrient and organic matter to the different fractions, samples were collected from the whole slurry management chain twice per month for 5 months (February-June 2018). The effect of different operating conditions of the two separators (i.e. pressure and velocity adjustment of the screw press and the centrifuge respectively) on the nutrient content of the resulting products was evaluated during equipment test runs. Based on experimental data from the farm, GHG emissions from the slurry management plant were estimated based on IPCC Guidelines (IPCC, 2006). To demonstrate the fertilizing value of the separated slurry fractions, the different products were utilized as organic fertilizers in a pot experiment with ryegrass and their performance was compared to mineral fertilizer treatments.

In most cases, results reveal a gradual decrease in the concentration of total solids and nutrients between raw slurry and liquid effluents from the first and second separation step (Table 1). The systems efficiency to remove dry matter from the raw slurry into solids showed an average value of 55.7% while the nutrient removal efficiency from the system peaked for P with 73.9% mass reduction. For total N, the efficiency of the system was 17.2%, a value significantly lower than the corresponding values for dry matter and total phosphorus. More than 65% of the total nitrogen content of the slurry was in the ammonium N (NH_4-N) form which is highly soluble and therefore, difficult to separate from the liquid phase mechanically. Moreover, the acidification induced decrease of pH at the liquid effluent significantly reduced its biomethane potential compared to the raw slurry.

Experiments are in progress and further results will be presented at the conference. Nevertheless, preliminary analysis of the results indicate that a swine manure management plant based on solid-liquid separation and acidification of the effluent liquid is useful for the management of the excessive nutrient amounts present on the farm. The solid fractions produced and exported from the farm contain 73.9% of the initial phosphorus content of the slurry therefore, significantly contributing towards reduction of phosphorus leaching risk near the farm. Moreover, implementation of acidification as a treatment of liquid manures shows a significant reduction in GHG emissions which might compensate the cost of introducing cleaner technologies.

Table 1. Mean characteristics of the initial slurry and the resulting liquid fractions after screw press and centrifuge separation, including total solids (TS), volatile solids (VS), total nitrogen (N_{tot}), ammonium nitrogen (NH^4-N), total C (C_{tot}) contents, pH and EC. Standard error is shown in brackets (n=7). The system's efficiency to concentrate nutrient on the produced and exported solid fractions was estimated as *System efficiency (mass basis) = [(System load-system effluent)/system load] * 100*

Parameter	Raw slurry	Liquid from screw press	Liquid from centrifuge	Acidified liquid effluent	Systems efficiency (mass basis) (%)
TS (g L^{-1})	41.1 (4)	32.1 (1.6)	20.0 (0.1)	19.4 (0.2)	55.7
VS (% TS)	76.7 (0.3)	71.5 (0.5)	69.6 (0.4)	65.0 (1.7)	60.1
N_{tot} (g L^{-1})	3.7 (0.1)	3.6 (0.0)	3.3 (0.1)	3.6 (0.2)	17.2
NH^4-N (g L^{-1})	2.4 (0.1)	2.4 (0.0)	2.1 (0.1)	2.1 (0.0)	20.1
C_{tot} (g L^{-1})	18.0 (1.1)	13.2 (1.3)	8.6 (0.3)	8.6 (0.7)	56.7
P_{tot} (g L^{-1})	0.9 (0.1)	0.8 (0.1)	0.3 (0.0)	0.3 (0.0)	73.9
pH	7.3 (0.1)	7.3 (0.1)	7.4 (0.1)	6.0 (0.1)	-
EC (mS cm^{-1})	22.8 (1.7)	23.0 (1.7)	23.2 (0.3)	23.7(0.5)	-

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