Pig slurry separation using different separation technologies: nutrients plant availability of the resulting liquid and solid fractions

Fangueiro David, Olsen Leandro, Cabral Fernanda, Vasconcelos Ernesto
Univ Tecn Lisboa, ISA; UIQA, Tapada da Ajuda; 1349-017 Lisboa; Portugal
*Corresponding author: dfangueiro@isa.utl.pt

Abstract
A pot experiment was performed to asses the agronomic value of 5 liquid and 5 solid fractions obtained by solid-liquid separation of pig slurry using 5 different techniques. The yields obtained with the LFs were significantly higher than with the SFs and in many cases, higher than in treatment receiving the untreated slurry. For most separation techniques, the application of LF led to an higher N recovery relative to the respective SF. Nevertheless, the P supplied by LF may not be enough to fully fulfil the plant requirements. Globally, the separation technique used influences more significantly the agronomic value of the liquid fraction relative to the solid fraction.

Introduction
Slurry solid-liquid separation is now widely used at farm level for slurry management [1]. The end products, a solid fraction (SF) and a liquid fraction (LF) are generally applied to soil as source of nutrients and organic matter. Special attention was given in published studies to the efficiency of separation techniques but the quality/composition of the SF and LF has been poorly evaluated even if recent studies showed that the composition of the resulting fractions depends strongly on the separation technology [2]. Consequently, the N:P:K ratio of LF and SF may be quite imbalance relative to the N:P:K ratio of plant demands. Furthermore, a large fraction of the total nitrogen applied to soil via the slurry, LD or SF is in the organic form and need to be mineralized to become available for plants [3]. Since the amount of slurry applied is based on the equivalent amount of total N, the higher the amount of N potentially mineralized the higher the amount of N potentially available for plant. Our hypothesis is that the separation technique may influence the N, P, K plant availability of the resulting SF and LF since it affects its composition. Hence, the aim of the present work was to assess the agronomic efficiency of SFs and LFs obtained from different separation techniques.

Material and Methods
Five LFs (-L) and five SFs (-S) were obtained by separation of the whole pig slurry (WS) using the following techniques: centrifugation (Cent-), sieving at 2mm (Siev-), sediment settling (Sed-), ,enhanced settling using cationic polyacrylamide (PAM-), sieving + PAM addition to liquid fraction (Siev+PAM-). The main parameters are reported in Table 1 (more details available in [2])

Table 1: N, P and K concentrations in the WS, LFs and SFs used (mean and standard error of 4 replicates)

	WS	Cent-L	Cent-S	Siev-L	Siev-S	Sed-L	Sed-S	PAM-L	PAM-S	Siev + PAM-L	Siev + PAM-S
Total N ($g\ Kg^{-1}$)	4.2 (0.1)	1.4 (0.1)	10.4 (0.1)	4.1 (1.7)	6.0 (0.3)	1.4 (0.1)	4.3 (0.2)	1.4 (0.0)	5.0 (0.1)	1.4 (0.0)	4.6 (0.1)
Total P ($g\ Kg^{-1}$)	1.1 (0.1)	0.02 (0.00)	5.7 (0.6)	0.04 (0.00)	3.5 (0.5)	0.04 (0.00)	1.8 (0.1)	0.04 (0.00)	1.9 (0.1)	0.04 (0.00)	2.3 (0.1)
Total K ($g\ kg^{-1}$)	1.8 (0.0)	1.1 (0.1)	1.7 (0.1)	1.4 (0.1)	1.5 (0.1)	1.0 (0.0)	1.3 (0.1)	1.0 (0.0)	1.3 (0.0)	1.1 (0.1)	1.4 (0. 1)

A pot experiment was performed with annual ryegrass (Lolium multiflorum Lam). For this, an amount of each slurry fraction was applied to 2 kg of a sandy soil at a rate of 250 kg N ha^{-1} and the resulting mixture was placed in a 3 L pot. Four replicates were performed for each treatment and a control treatment (no fertilization) was also considered. The ryegrass was seeded 7 days after SF or LF application. Two cuts were carried out and for each one, the plant yield as well as the N, P and K content of the dry material were evaluated.

The data obtained here were treated by analysis of variance (one way-ANOVA) and the least significant difference (LSD) test based on a *t*-test at a 0.05 probability level was used to assess the statistical significance of the mean differences.

Results

Significantly higher yields were obtained in treatments receiving LFs (5.28 to 5.93 g of dry matter per pot) than in SFs (4.28 to 4.53 g of dry matter per pot) amended soils (Figure 1). It is to note that the differences between LF and SF treatments in terms of yields remained constant in both ryegrass cuts. It indicates that even after plant removal of the available N initially present in slurry fractions (mineral nitrogen), the LF continue to purchase more N than the solid fraction. Furthermore, Cent-L+S, PAM-L+S and SievPAM-L+S treatments led to yields significantly higher than in WS in both cuts. Such differences were probably due to the NH_4^+:total N ratio of the different fractions that directly affect the N availability for plants (see [2]). The total yields obtained with SFs were not significantly different and in most cases, significantly lower than in WS treatment.

The PAM-L and Siev+PAM-L treatments led to the higher yields in the first cut and considering the total yields, the higher values were observed in these two treatments and in the Cent-L.

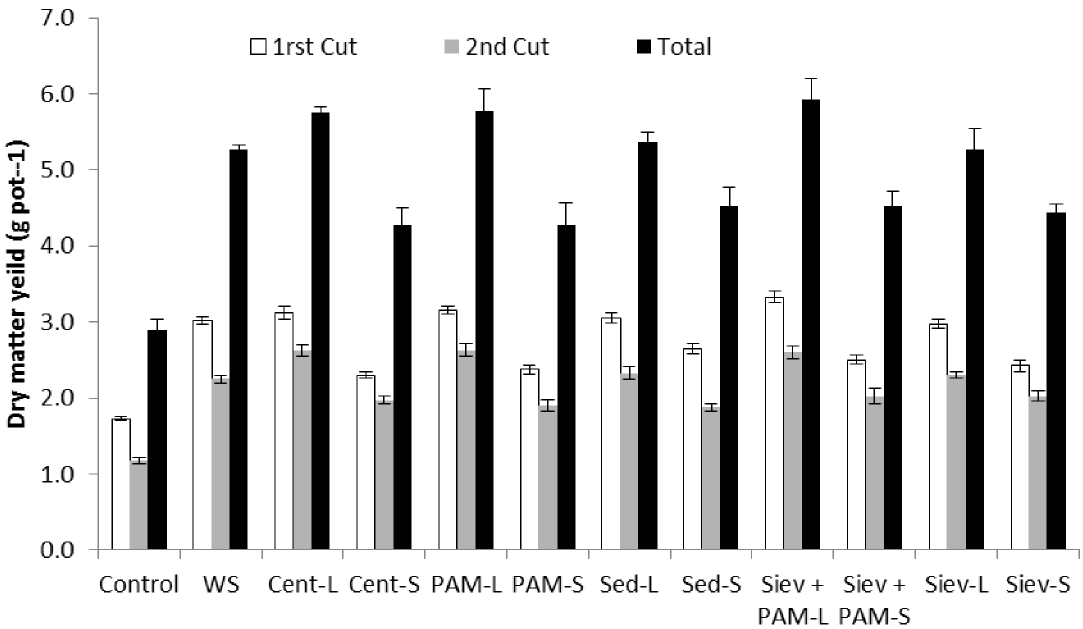

Figure 1. Dry matter yield of aerial biomass obtained at each cut; mean and standard error of 4 replicates.

The N concentration in plants from the first cut was significantly higher than in plants from the second cut whereas in the case of the K concentrations differences were not so great, namely in the SFs treatment (Figure 2). It is still to refer that similar P concentrations were observed in both cuts in most treatments. At the first cut, higher N and K concentrations were observed in treatments with LF than in respective SF. However, for the second cut, higher N and P concentrations were observed in treatments amended with SFs (even if not always statistically significant) whereas the K concentration in plants was similar in all treatments.

The differences between the LFs and SFs in terms of plant nutrition were highlighted when comparing the N, P and K recovery by plants.

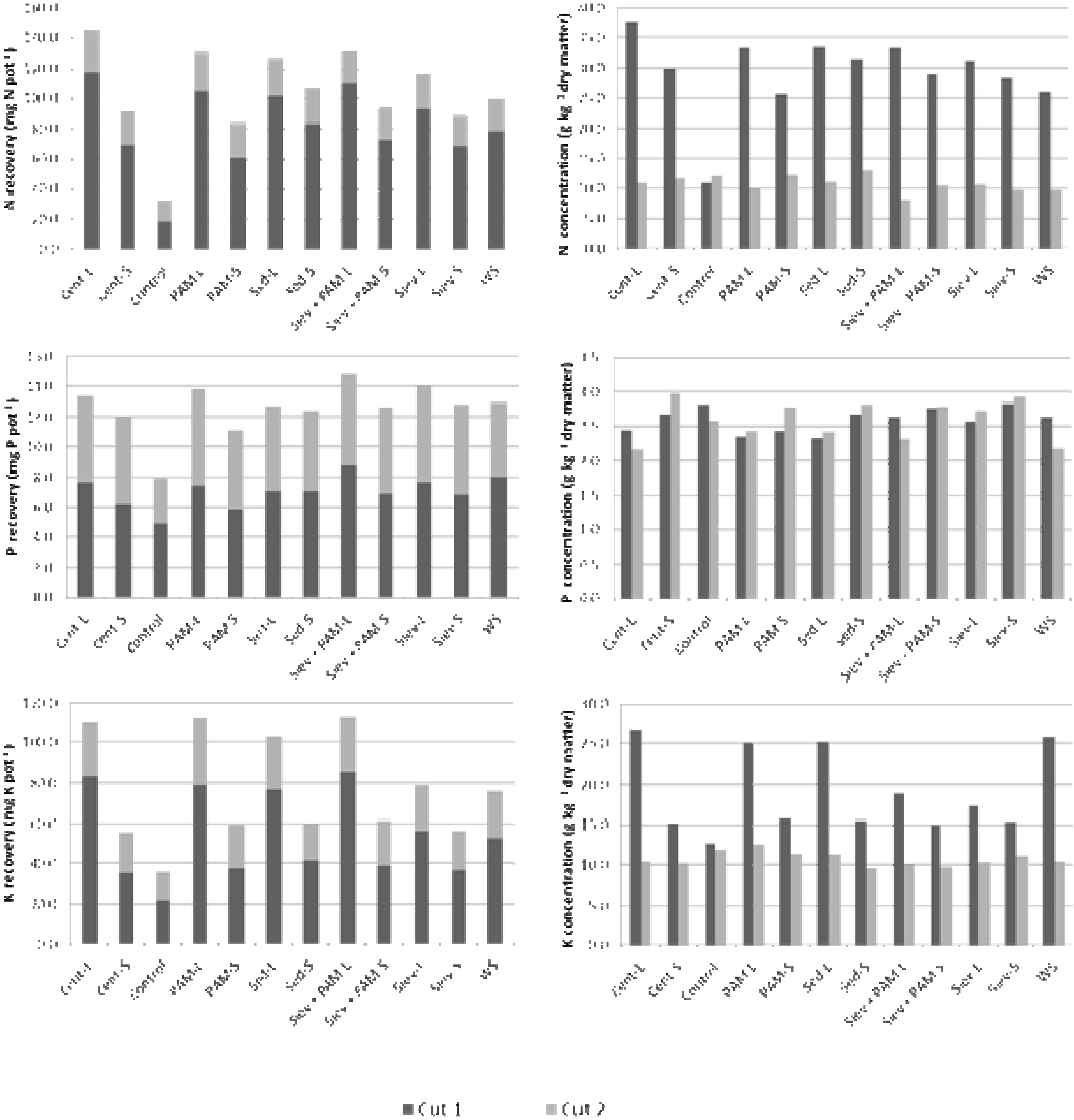

Figure 2. N, P and K concentration and recovery in plants harvested in cut 1 and cut 2 in the treatments considered here -mean of 4 replicates.

The N recovery for the 1^{rst} cut in the Cent-L, D-L, PAM-L and Siev+PAM-L amended soil was higher than 100 mg N per pot whereas in all SFs and WS amended soil, N recovery was lower than 85 mgN. The differences between SFs and LFs amended soil in terms of N recovery were not so significant for the second harvest with values ranging from 19 to 28 mg N pot^{-1} in all amended treatments. A good relationship (R2=0.8073) was observed between the total N recovery and the amount of NH_4^+-N applied in the different treatments suggesting that this is a major parameter to be considered when applying organic fertilizers to soil.

Close to 90% of the total N recovery occurred until the first cut indicating that most of the available N was quickly removed by plants and low or no nitrogen mineralization occurred afterward. An equivalent amount of 60-80% of the NH_4^+-N applied was removed in the LFs amended soil except the Siev-L treatment where the amount of N recovery was higher than the amount of NH_4^+ applied as occurred in all SFs.

The differences between treatments in terms of K recovery were similar to those observed for nitrogen.

It is to refer that in all LF treatments except the Sed-L+S, the amount of P applied was lower than the amount of P recovered by the plant whereas in the SF treatments, less than 10% of the applied P was recovered by the plants. This is the critical point relative to slurry separation since a single application of LF may not be enough to supply the required P to plants whereas single application of SF may lead to P accumulation in soil or P losses to waters. None of the separation techniques used here led to balanced fractions in terms of P but separation by sedimentation appears as the most efficient option since it supplied enough P for plant growth via LF and the SF led to the higher P recovery relative to other SFs.

Conclusion and perspectives

All the LFs obtained led to higher yields than SFs and, can consequently fully substitute the whole slurry for basal fertilization. SFs should ideally be applied before sowing to allow for organic N mineralisation and complemented with an application of LF after the first cut. The separation technique used may influence the yields obtained after LF application but has a poor impact on the fertilizer value of the SF.

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