Effect of different slurry pre–treatments on mechanical separation methods efficiency: preliminary results.

(Article begins on next page)

Effect of different slurry pre–treatments on mechanical separation methods efficiency: preliminary results

Popovic Olga, Gioelli Fabrizio, Dinuccio Elio and Balsari Paolo
University of Torino, Department of Agriculture, Forestry and Food Sciences, Torino, Italy
Email: olga.popovic@unito.it

Abstract
Chemical pre-treatment of manure is crucial in meeting most of separation objectives and achieving proper solid-liquid separation process. Efficiency of mechanical separators usually (mostly) depends on the type of manure (DM content) and on its capacity to remove small particles to the solid fraction. This study focuses on effect of biochar addition to raw slurry of two different polymers. Effect of polymer addition to co-digestate has also been assessed. Biochar addition to raw slurry increases the efficiency of chemical-mechanical separation. Synthetic polymer (PAM) did not show any affect on separation efficiency of co-digestate. Biochar addition and anaerobic digestion increase the effect of chitosan. Effect of biochar addition to raw slurry on separation efficiency is time dependent.

Introduction
Solid-liquid separation of manure has proved to be useful on many farms and it is usually done using separators based on screw press or decanting centrifuge. The final products of these separations are nutrient and energy rich low volume solid fraction (can be exported to outside farm areas more conveniently) and liquid fraction rich in ammonia (can be used as local nitrogen and water source). However, the efficiency of mechanical separators is depending on the thickness of raw input manure and it is often limited by separator capability to remove nutrient rich particles (usually smaller than 25 µm in diameter) to solid fraction. In general, the efficiency of mechanical separators in removing smaller particles to solid is often not satisfactory. In order to meet majority of separation objectives polymer flocculation prior to mechanical separation proved to be leading technique [1]. In most of the cases flocculation is done with the use of synthetic polymers (polyacrylamide-PAM). As natural flocculants are often by-products [3] of some large scale production, their use in separation may have advantages over the synthetic polymers due to its lower price. Thin (diluted) raw slurry (approx. 1.5% dry matter content) is often produced, especially on the farms where water is used to clean the barns. The effectiveness of separation of thin slurry, in terms of dry matter, is usually not satisfactory. So, addition of biochar to pig slurry prior to polymer addition followed by mechanical separation can possibly improve the efficiency, as it would increase dry matter content of the final input to separator.
Anaerobic co-digestion of slurry is a very good option to reduce organic matter and odours, reduce pathogens and produce energy and this technique has widespread in the last years. Co-digestate produced from pig slurry usually contains very low amount of dry matter and thus reduces the efficiency of mechanical separators. The use of flocculants prior to separation of co-digestate can affect the efficiency of mechanical separators. However, the literature on this topic is very scarce.
Thus the aim of this study was to determine if there is an effect of biochar addition and anaerobic digestion on separatioin efficiency when synthetic polymer (PAM) and natural polymer (Chitosan) are used as chemical pre-treatments.
The main objectives of this study were:

1. Optimization of PAM and chitosan dosages for raw and biochared pig slurry and co-digestate
2. Determine if there is any affect of biochar time application to separation efficiency of both polymers (PAM and chitosan)

Material and methods
Raw pig slurry and co-digestate were collected from fattening pig farm units and were separated by gravity drainage for 20 minutes through sieve with 2 mm mesh openings. Three pre-treatments (biochar and two flocculants) were introduced to raw slurry and co-digestate prior to separation.
Flocculation was performed using synthetic polyacrilamide-PAM polymer (superfloc C-2260, cationic, linear, high molecular weight, 40% charge density, Kemira Kemwater, Finland) and natural polymer chitosan (biodregradable, non-toxic, polycationic, practical grade supplied by Sigma-Aldrich Inc.). PAM was dissolved in water for a final concentration of 0.2% and 5 polymer rate treatments were applied in

incensement of 25ml/500ml in dosage range of 0-225ml. Chitosan was dissolved in 2% acetic acid [4] for a final concentration of 0.45%. Optimal chitosan dosage was determined using 4 polymer rate treatments applied in incensement of 60ml/500ml in dosage range of 0-240ml. Biochar was collected from gasification unit (Agriindustria Di Tecco G&C S.N.C., Italy) where wood chips were gasified at 1300°C.

Flocculants dosage optimization

The optimal dosage of flocculants for each manure type (raw and biochared slurry and co-digestate) was determined based on mass separation, achieved Simple (Et) and Reduced (Et') separation efficiency, visual characterisation of flocs size, solid and liquid fraction dry matter content, and visual estimate of liquid fraction turbidity. The effect of biochar addition alone and in combination with flocculants on mass separation, separation efficiency and dry matter content of produced separates was tested. Simple separation index (Et) stated the distribution of compound x between the solid and liquid separation fractions, and range from 0 to 1, where e.g., Et(x)=0.70 indicates that 70% of x is present in the solid fraction. Reduced separation index (Et') ranges form -1 to 1, with positive values indicating an increase in the concentration of x in the solid fraction compared with the raw slurry, and negative values are indicating an increase of the concentration of x in the liquid fraction.

Time of application of biochar to slurry with and without flocculants

About 5g of biochar was added to 500ml of raw slurry in order to increase its dry matter content for 1%. Separation of raw (as a control), biochared, and flocculated biochared slurry was carried out immediately (Time 1) and 24 hours after biochar addition (Time 2). Optimal dosage of flocculants to biochared slurry was added prior to separation. Mass of upper and lower solid layer formed were measured separately, being mixed together prior to dry matter analyses. The effect of biochar addition alone and in combination with flocculants on mass separation, separation efficiency and dry matter content of produced separates was tested.

All solid and liquid separates will be analysed for total dry matter, N, P and K.

Result and discussion

Measured dry matter content of pig slurry (4.8%) and co-digestate (4.6%) were similar to those previously found on farms [1]. After biochar addition the dry matter content of raw slurry increased up to 6%DM.

The efficiency of chemical-mechanical separation depends on the type of polymer used and its optimal dose which may change with the conditions on the individual farm units (e.g. process or flow conditions, polymer mixing intensity and time allowed for mixing). These changes may lead to poor operation of mechanical separator. The optimal flocculant dosages also vary greatly between the farm units due to the large variation between slurries.

After PAM and chitosan addition, simple (Et) and reduced (Et') separation index for dry matter were not significantly affected by addition of different dosages of polymer (Table 1 and 2). Lack of dosage effect when Et was calculated can be due to the poor performances of gravity drainage following chemical pre-treatment and due to the mass balance calculation (used for calculation of Et, see section 2). Addition of PAM to slurry increases the effective particle size by agglomeration of small particles into larger flocs, and gravity drainage retains particles >1000 µm in solid fraction. When low dosages of PAM (<125mlPAM/500ml slurry) and chitosan (<60ml chitosan/500ml slurry) were applied to slurry, lower amount of small particles was flocculated, so those unflocculated particles could clog the mash openings and increase the water retention in the solid fraction. Therefore, when lower dosages of PAM and chitosan were added, the low dry matter content (Figure 1 and 2) in large mass of solid fractions was produced.

When PAM was added to raw slurry, separatioin efficiency (Et and Et') was not influenced by addition of biochar (Table 1). Surprisingly, we could not see the effect of PAM increased dosages to co-digestate, nor any floc formation when PAM was added. Solids produced were with low DM% while liquid fraction contained high amount of particles (Figure 1). Therefore, no optimal dosage of PAM to treat co-digestate was determined. The lack of PAM affect on co-digestate is most probably due to the physical characteristics of co-digestate particles.

Table 1. Separation efficiencies of treatments with PAM addition to raw and biochared slurry and co-digestate prior to gravity drainage

	Simple sep. index Et (total solids)			Reduced sep. index Et' (total solids)		
Polymer dosages mlPAM/500ml manure	Raw slurry	Biochared slurry	Co-digestate	Raw slurry	Biochared slurry	Co-digestate
100	0.69a	0.63a	-	0.44a	0.44a	-
125	0.67a	0.60a	0.62a	0.43a	0.38a	0.39a
150	0.68a	0.69a	0.60b	0.45a	0.53a	0.37a
175	0.69a	0.66a	0.60b	0.44a	0.49a	0.39a
200	0.68a	0.63a	0.59b	0.44a	0.45a	0.37a
225	-	-	0.55a	-	-	0.34a

For chitosan addition to the raw, biochared slurry and co-digestate we have observed that separation efficiency of the same chitosan dosage was significantly higher when applied to biochared slurry and co-digestate than when it was applied to raw slurry (Table 2).

Table 2. Separation efficiencies of treatments with chitosan addition to raw and biochared slurry and co-digestate prior to gravity drainage

	Simple sep. index Et (total solids)			Reduced sep. index Et' (total solids)		
Polymer dosages mlCHIT/500ml	Raw slurry	Biochared slurry	Co-digestate	Raw slurry	Biochared slurry	Co-digestate
60	0.33a	0.74b	0.71b	-0.16a	0.52b	0.29ab
120	0.49a	0.70ab	0.79b	0.23a	0.49a	0.62a
180	0.41a	0.59b	0.76b	0.13a	0.41b	0.62b
240	0.23a	0.46a	0.70b	-0.05a	0.25ab	0.54b

For raw and biochared slurry the changes in dry matter content of solid fractions after polymer addition were following expected pattern. Previous study [1] showed that flocculation will take place until the optimal dosage of polymer is reached. Continuation of polymer addition will lead to total deflocculation of slurry. For raw and biochared slurry we have observed that the dry matter, so thus the turbidity of liquid fractions decreased with increasing PAM and chitosan dosages. The dry matter content of solid fraction at the same PAM dosage was higher for biochared than for raw slurry. In the liquid fraction, the dry matter content was not markedly different for raw and biochared slurry (Figure 1). The rationale behind the choice of 175mlPAM/500ml raw slurry and 150mlPAM/500ml biochared slurry; dosage is based on efficiency (see the separation efficiency in terms of DM) and economical parameters (introduce lower amount of diluted polymer to input slurry).

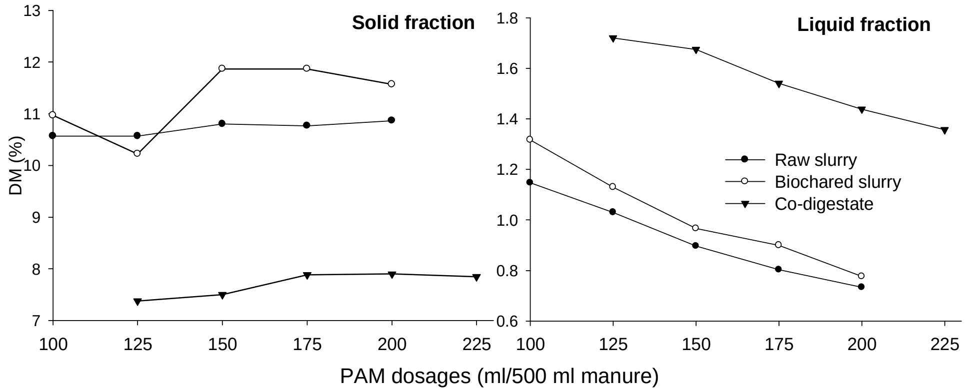

Figure 1. Solid and liquid fractions dry matter after different PAM dosages addition to raw and biochared slurry and co-digestate prior to gravity drainage

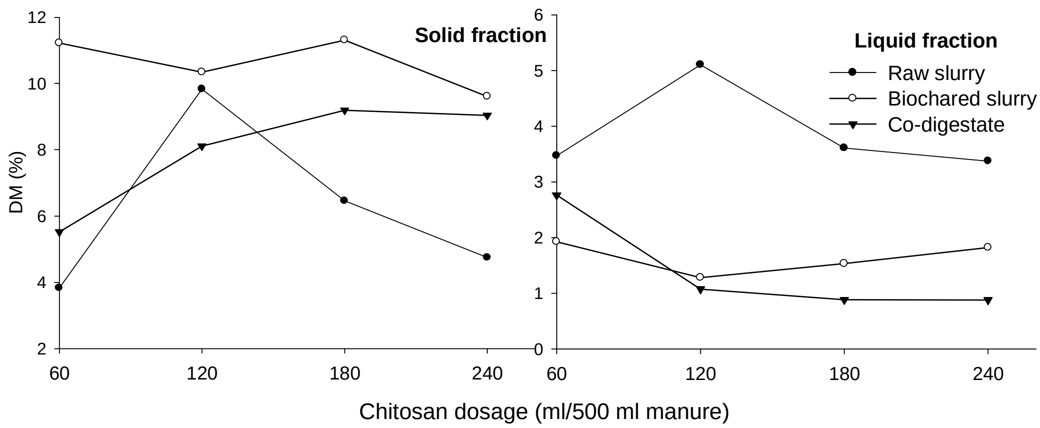

Figure 2. Solid and liquid fractions dry matter after different chitosan dosages addition to raw and biochared slurry and co-digestate prior to gravity drainage

When 120ml of chitosan was added to 500ml of raw and biochared slurry and to co-digestate, the solid fraction with high dry matter and liquid fraction with the low dry matter content were produced.

Due to its chemical and physical characteristics, biochar floats on the surface of the slurry tank after its addition. When biochar was added to the slurry and polymers were added 24h later, separation performed better in terms of mass balance, Et and separation fraction characteristics (Table 3). Also, addition of biochar changed distribution of solids between upper and bottom layer in treatments when compared to their initial distribution in raw slurry. The share of upper layer out of total solid increased (up to 17 times) and, when slurry was treated with biochar and chitosan, up-layer contained almost equal amount of solids as in lower layer. Presence of the upper layer can lower ammonia losses during storage, as well as lower the gaseous emission.

Table 3. Effect of time application of biochar on polymers (PAM and chitosan) performances

		Raw slurry	**Biochared slurry**	**Biochared slurry with PAM**	**Biochared slurry with chitosan**
t=1	Mass balance (%)	38	42	47	83
	Et (DM) (%)	64	82	115	142
	Solid fraction DM (%)	7.9	8.4	11.1	7.4
	Liquid fraction DM (%)	3.2	3.5	0.9	1.5
t=2	Mass balance	42	50	44	64
	Et (DM) (%)	67	107	111	168
	Solid fraction DM (%)	7.75	9.41	11.4	11.3
	Liquid fraction DM (%)	1.43	1.99	1.37	1.53

Conclusion and perspectives

Addition of biochar and flocculants increase mass separation efficiency of mechanical separators. Addition of PAM to biochared slurry showed the highest separation efficiency. There has been no effect of PAM addition to co-digestate. Effect of biochar addition to raw slurry on separation efficiency is time dependent. The results obtained from this study should be used for finding optimal combination of chemical pre-treatment and separation method for raw slurry and co-digestate.

References

[1] Hjorth M, Christensen KV, Christensen ML, Sommer SG, 2010. Solid-liquid separation of animal slurry in theory and practice. A review. Agronomy for Sustainable Development, 30, 153-180.
[2] Popovic O, Hjorth M, Jensen LS, 2012. Phosphorus, copper and zinc in solid and liquid fractions from full-scale and laboratory-separated pig slurry. Environmental Technology 33, 2119-2131.
[3] Salehizadeh H, Shojaosadati SA, 2001. Extracellular biopolumeric flocculants. Recent trends and biotechnological importance. Biotechnology Advances 19, 371-385.
[4] No HK, Meyers SP, 1989.Crawfish chitosan as a coagulant in recovery of organic compounds from seafood processing streams. Journal of agricultural and food chemicstry. 37, 580-583.