

INFLUENCE OF TWO DIFFERENT SOLID-LIQUID SEPARATION PROCESSES ON THE SETTLING CHARACTERISTICS OF SWINE EFFLUENT

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ABSTRACT: Solid-liquid separation (SLS) in swine manure treatment is an important step due to a substantial amount of organic and inorganic solids that can be removed from liquid wastewater. The aim of this study was to evaluate the efficiency of two mechanical separation processes (screw press and rotary screen) followed by settling and to analyze the composition of liquid fractions. In this sense, total solids (TS), volatile solids (VS), fixed solids (FS), total phosphorous (TP), total Kjeldahl nitrogen (TKN) and total organic carbon (TOC) were analyzed. By combining mechanical separation with settling, the average of TS, VS and FS removal was 75%, 80% and 69%, respectively. Phosphorus removal reached 86%, and TKN achieved a reduction up to 45%. There was no statistical difference among the results obtained using SLS by screw press and rotary screen. It was possible to conclude that SLS process with mechanical devices, followed by settling, generates a suitable effluent to be used on nitrification and denitrification process, producing an effluent with a C/N ratio of 2.6, and the solid fraction is useful to anaerobic digestion.

Keywords: nitrification/denitrification, mechanical separation, settling process.

INTRODUCTION

The world population growth made a strong pressure over agricultural and industries sectors, obligating them to produce more to attend products demand. As an outcome of this, the environment management of residues must be considered (KUNZ et al., 2005).

Swine chain is well known for its polluter potential, due to high organic loads, nutrients (mainly nitrogen and phosphorus), pathogens, heavy metals, sediments, antibiotics and hormones. Therefore, the treatment of wastewater to reduce these pollutants is widely recommended when soil support capacity is exceeded (HUTCHINGS et al., 2013). The high animal concentration in concentrated animal feeding operation (CAFOs) also increase the waste generation per area and point out a very intensive environmental contamination (TORRES et al., 2013).

The presence of high nitrogen loads in swine manure can cause severe damages to the environment. Nitrification and denitrification by Lutzack-Ettinger modified process is an efficient process used for nitrogen removal. However, high organic loads could cause interferences in this process and, therefore, a raw manure pretreatment step is necessary, usually, a solid-liquid separation (SLS) (RIANO & GARCÍA-GONZÁLEZ, 2014).

SLS technologies can be applied to improve wastewater treatment, mainly for total or suspended solids reduction (JØRGENSEN & JENSEN, 2009). The SLS technology is a strategy used as a first step in advanced treatment processes, aiming to produce a suitable affluent for subsequent treatment processes (HJORTH et al., 2010).

Depending on the SLS technology used, there will have significant differences in the physical and chemical properties of the solids and resulting liquid effluent. Furthermore, other factors have direct relation to these properties, as manure storage conditions and animals diet (BURTON, 2007).

The present study aims to compare SLS efficiency on swine manure using rotary screen and screw press followed by settling, to pretreat an affluent for subsequent nitrogen removal process.

MATERIAL AND METHODS

The swine manure used in this study was collected at the experimental system of the Embrapa Swine and Poultry in Concordia, Santa Catarina State, Brazil (27°18'S, 51°59'W). Samples of fresh manure from farrowing sows house were collected directly from the

reception pits, after treatment by rotary screen (2 mm) and screw press (2 mm). For comparison of results, a sample before mechanical separation process (raw manure) was also collected.

Samples of raw manure and after treatment by rotary screen and screw press were settled in an Imhoff cone during 1h30min (APHA, 2012), for settleable solids determination and to test separation efficiency. The supernatant phase was taken for further characterization analysis as described below. Considering that each step of swine production generates manure with different characteristics and volumes (supernatant and sludge), manure samples from gestation sows house, nursery house and farrowing sows house were also collected for settleable solids determination and results were compared.

For liquid fractions characterization, the following parameters were analyzed: total solids (TS), volatile solids (VS), fixed solids (FS) (APHA, 2012). Additionally, total Kjeldahl nitrogen (TKN) was determined by titration after samples digestion and distillation, and total phosphorus (TP) was determined by spectrophotometry (APHA, 2012). Total organic carbon (TOC) was determined in supernatant samples of screw press and rotary screen using an elemental analyzer (Multi C/N 2100, Analytik Jena) equipped with a module for liquid samples analysis. The other samples used in this work (raw manure, after rotary screen, after screw press, raw manure supernatant) could not be analyzed for TOC determination due to their high solid content.

RESULTS AND DISCUSSION

Results of samples characterization after SLS are shown on Table 1. TS in raw manure was of 17.33 g L^{-1} , and after settling (raw manure supernatant) TS was of 5.80 g L^{-1} , corresponding to 67% of reduction. There was no significant difference (student test, $p < 0.005$) on TS among samples after rotary screen and screw press in both cases: without and after sedimentation. In the same way, there was no significant difference on results of VS, FS, TKN, TP obtained for samples of rotary screen and screw press.

The mechanical separation (screw press and rotary screen) followed by sedimentation, resulted on a reduction of TKN up to 45% compared to raw manure. According to Jørgensen et al. (2009), the nitrogen removal in SLS processes basically comprehends the organic nitrogen, while ammonium stills remains on the supernatant, highlighting the importance to treat this fraction.

The FS content in swine manure could cause problems in treatment systems. In this study, a good reduction of FS was obtained (up to 69%). Volatile solids could be considered as a rough approximation of the amount of organic carbon. In this work, VS were used to predict carbon reduction efficiency, once TOC was determined only on supernatant samples of rotary screen and screw press, making impossible the comparison with samples without solids separation. According to the results showed on Table 1, a reduction of VS up to 80% was obtained after mechanical separation processes (screw press and rotary screen) followed by settling (compared to raw manure). Results for TOC in supernatant after sedimentation samples of screw press and rotary screen were of 2.56 g L^{-1} and 2.89 g L^{-1} , and are in agreement with VS in the same samples, showing that our approximation could be considered as true.

The carbon for subsequent wastewater treatment by conventional process of nitrogen removal (nitrification and denitrification) is important, once denitrification efficiency is related to the biodegradable amount of substrate available (carbon/nitrogen ratio, C/N). Considering that the TOC and TKN results in samples of screw press and rotary screen supernatant were not statistically different, the calculated C/N ratio is about 2.6 in both supernatant samples (screw press and rotary screen).

The ideal C/N ratio for total nitrification/denitrification is variable and different values are reported in literature. The reactor configuration and carbon biodegradability are factors which has direct influence in the C/N ratio for nitrogen removal (WEF, 2010). Bortoli (2010) evaluated a system for nitrogen removal from swine wastewater based on Lutzak-Ettinger modified process and obtained 96.4% and 90.3% efficiency of carbon and nitrogen removal, respectively, using C/N ratio of 2.5. Therefore, it is expected that the SLS method proposed in this work would be suitable to be combined with a subsequent nitrogen removal step based on Lutzak-Ettinger modified process. It is important to point out that this kind of

effluent have a relatively high carbon content compared to sanitary wastewater, for example, which is an advantage in modified Lutzak-Ettinger process because in this case the addition of an external source of organic carbon is not necessary.

Regarding to TP, the comparison of results obtained for supernatant of mechanical separation processes with raw manure, showed that it was a phosphorus reduction of 86%, and, again it was no significant difference ($p < 0,005$) between both mechanical processes evaluated. This high phosphorus removal efficiency is due to the fact that most of it is suspended and not dissolved in the raw manure, since the phosphorus solubilizes according that degrades the raw manure (KUNZ et al, 2010).

As mention before SLS processes results in two fractions: liquid fraction, which may be treated for nitrogen removal (nitrification and denitrification), and solid fraction, that could be treated by anaerobic digestion. Amaral et al. (2016) studied SLS strategies at effluents of different swine production phases, aiming to verify the potential of biogas production. They showed that solids from effluents such as that ones used in this work have a potential for biogas production of $0.476 \text{ m}^3_{\text{N CH}_4} \cdot \text{kg}_{\text{SV add}}^{-1}$ while solids from rotary screen and raw manure have a potential for biogas production of $0.534 \text{ m}^3_{\text{N CH}_4} \cdot \text{kg}_{\text{SV add}}^{-1}$ and $0.479 \text{ m}^3_{\text{N CH}_4} \cdot \text{kg}_{\text{SV add}}^{-1}$, respectively. These results proved the feasibility of using SLS, since it is possible to treat the different fractions for nitrogen removal and still having a potential energy use.

The swine production phase has a direct influence over solid characteristics, as can be observed below (Figure 1). The settling process behavior is different as well as the sludge volume, consequently gas production and nutrients concentration in supernatant are variable as already reported by Amaral et al. (2016). In this context, for the perfect scaling of effluents treatment systems these factors must be carefully observed (BURTON, 2007).

The results obtained in this work are according to the results observed in literature, with the advantage that the use of additives is not necessary. Kunz et al. (2010) evaluated phase separation efficiency on a SLS system treating raw manure with addition of organic coagulants. In another work, Riaño & García-González (2014) monitored a swine waste treatment plant with screw press followed by a float decantation to removal the solids fraction. In these works, chemical additives were used to improve solid settling and in the present study the settling process occurs just with gravity action. Therefore, it is possible to have a decrease in treatment system costs and improve operational handling (BURTON, 2007).

CONCLUSION

High efficiency was observed in the solids removal by the gravity action, which entails lower costs in the construction and operation of a wastewater treatment plant in comparison with the use of chemical additives. The TKN and carbon reduction obtained applying SLS would result in oxygen economy and reduces the reactor silting risk, increasing the system efficiency. The C/N ratio obtained and effluents after SLS (screw press or rotary screen) followed by sedimentation could be considered suitable for subsequent treatment by Lutzak-Ettinger modified process, based on previous work, indicating that these processes could be used ahead of nitrification and denitrification process to CAFOs wastewater treatment. Additionally, the solid fraction that become from SLS presents potential for biogas production through anaerobic digestion.

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Table 1. Swine wastewater characteristics after different solid-liquid separation processes.

	TS (g L ⁻¹)	VS (g L ⁻¹)	FS (g L ⁻¹)	TKN (g L ⁻¹)	TP (g L ⁻¹)
Raw manure	17.33	11.65	5.68	1.60	0.44
After rotary screen	11.14	6.60	4.55	1.33	0.35
After screw press	10.30	6.63	3.66	1.15	0.27
Raw manure supernatant	5.80	3.41	2.38	1.16	0.085
Rotary screen supernatant	4.45	2.52	1.93	0.94	0.059
Screw press supernatant	4.10	2.33	1.76	0.88	0.063

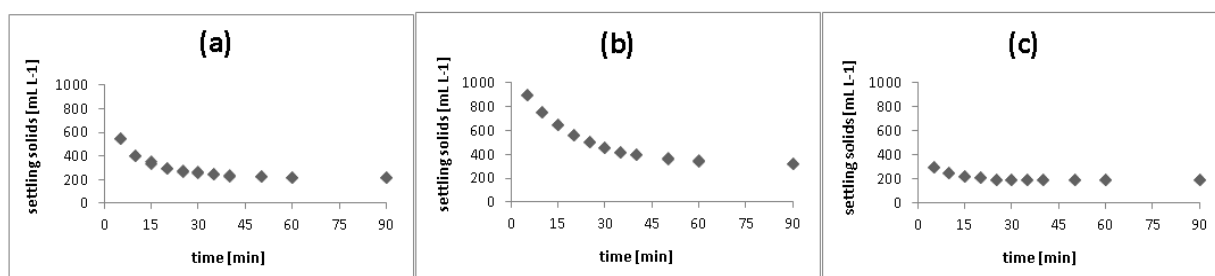


Figure 1. Settling curves of the raw manure after mechanical separation. (a) Gestation sows house (b) Nursery house (c) Farrowing sows house.