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Ammonia recovery by gas-permeable membranes enhances anaerobic digestion of swine manure

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Abstract: In this study, gas permeable membrane technology was used to capture ammonia (NH_3) during the anaerobic digestion (AD) process, eliminating one of the main inhibitors of the AD process. The results showed an improvement in the production of biogas from swine manure. The technology also captured nitrogen in the form of an ammonium salt that can be re-used as fertilizer.

Keywords: anaerobic digestion, gas-permeable membrane, ammonia capture.

In many European countries, anaerobic digestion (AD) process is widely used to treat manure. However, the inhibition of methanogens by high ammonia (NH_3) concentration in high-strength manure severely reduces the biogas production using AD process (Garcia-González et al., 2015). A new technology based on gas-permeable membranes (GPM) has been evaluated for NH_3 recovery from manure and anaerobically digested effluents (Vanotti et al., 2015). In the present study, the influence of a GPM system, with the active capture inside an AD reactor, was evaluated both in terms of methane (CH_4) production and biogas composition. Ammonia recovery by the GPM system was also evaluated. For that, batch and semi-continuous AD of swine manure retrofitted with a GPM system were investigated and compared to a control treatment (i.e. anaerobic digestion of swine manure without ammonia recovery).

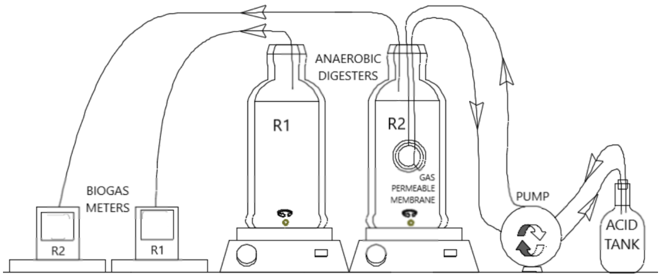

Fig. 1. Schematic of the experimental set-up.

Two stirred tank reactors with a working volume of 2 L were used (Fig. 1): one reactor (R1) was used as a control treatment for AD of swine manure (without NH_3 recovery), and the other reactor (R2) was used for AD of swine manure coupled with a GPM system (with NH_3 recovery). Temperature was kept constant (38ºC) in both reactors. The gas-permeable membrane used was tubular (hollow) made of e-PTFE material with a length of 53 cm, an outer diameter of 5.2 mm and a wall thickness of

0.56 mm. Membrane density was 0.95 g/cm^3. An acidic solution (150 mL of H_2SO_4 1N) was continuously recirculated through the inside of the tubular membrane using a peristaltic pump. The acidic solution was used as a trapping solution to recover NH_3 as $(NH_4)_2SO_4$ solution, which can be used as a fertilizer.

Two sets of experiments were carried out. The first one was a batch AD process, conducted in triplicate. The two reactors (with and without NH_3 recovery) were identically fed with swine manure with a substrate to inoculum ratio of 1:1 (g VS : g VS). Each batch anaerobic experiment lasted 10 days. In the second one, the same two reactors were fed semi-continuously with swine manure at an organic loading rate (OLR) of 2.4 g COD/L d, and at hydraulic retention time (HRT) of 7 d. Mean concentrations were 46.7 volatile solids (VS) g/L and 1.2 g total ammonia nitrogen (TAN)/L in the manure used for batch experiments and 7.4 g VS/L and 2.2 g TAN/L in the manure used for the semi-continuous experiment. The inoculum had a concentration of 16.3 g VS/L. In both experiments, biogas production was measured daily and biogas composition was analysed once per week. Acidic samples from the acid tank were collected daily to monitor pH and TAN concentration.

In the batch AD, an increase of specific methane yield of 19% was observed in R2 with NH_3 recovery compared with R1 without NH_3 recovery (Table 1). Moreover, the biogas obtained in R2 had a higher percentage of CH_4 (78%) compared to R1 (60%). TAN in the acidic solution of R2 increased up to 540 mg at day 10 with an average TAN recovery rate of 2.70 ± 0.7 g/m^2 d (Fig 2.A). In the semi-continuous AD, CH_4 productivity in R2 was 106% higher than in R1. Average TAN recovery rate in R2 was 3.97 ± 0.06 g/m^2 d, with 2047 mg of TAN recovered on day 21 (Fig 2.B).

Table 1. Effect of the gas-permeable membrane system in AD of swine manure.

	Specific methane yield (mL CH_4/g VS)		**Percentage of Methane (%)**	
	R1	**R2**	**R1**	**R2**
Batch	*66 (11)*	*77(2)*	*60 (4)*	*78 (0)*
Semi-continuous	*15 (2)*	*31(6)*	*34(2)*	*36(5)*

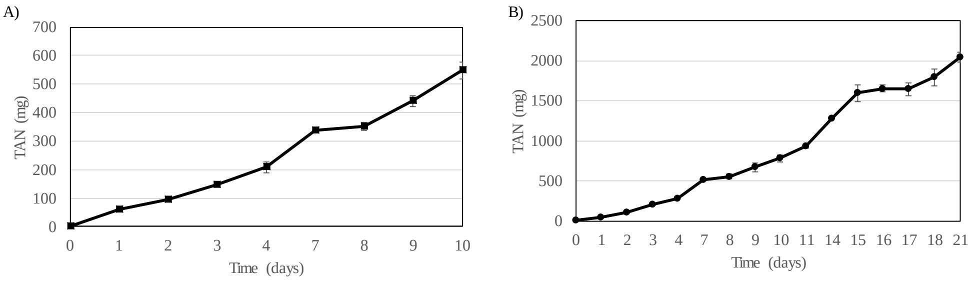

Figure 2. Mass of TAN captured during the experimental time in R2: A) Batch AD; B) Semi-continuous AD.

Results showed a great potential of gas-permeable technology to improve anaerobic digestion of swine manure while recovering ammonia from digester in form of an ammonium salt. This work could be included in the section "Next generation resource recovery - breakthrough technologies and value added products".

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