Post-hydrolysis ammonia-stripping to improve methane production potential from poultry manure

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Introduction

Ammonia-stripping has been used as a method for removing ammonia from feedstock characterized with high ammonia levels. The purpose of ammonia-removal is to avoid the perceived inhibition of the microorganisms' activities it causes in the anaerobic digestion (AD) process. Previous studies have established the fundamental concepts of ammonia-stripping in order to have an effective ammonia-removal system. Mainly, two approaches of ammonia-stripping were discussed in the literature: direct aeration of raw material and side-stream stripping of digestate (Abouelenien et al., 2010; Zhang et al., 2012). Each method has some disadvantages that prevent optimal conditions. For instance, raw samples have high organic nitrogen content and lower ammonia concentrations. Therefore, direct aeration of untreated samples may not prevent further ammonia generation by the decomposition of organic nitrogen. On the other hand, side-stream stripping has limitations in terms of the stripping gas; few studies referred to air or O_2 to be the best stripping gas but these options are detrimental to the methanogenic microorganisms in the digestate, thereby cannot be used in side-stream stripping (Yin et al., 2019).

In this study, post-hydrolysis ammonia stripping is proposed to address the shortcomings of the two conventional ammonia-stripping options. The merit of this approach falls in the fact that most organic nitrogen is transformed into ammonia during the hydrolysis, after which ammonia increments decrease. At this stage of the AD, no inoculum is added and air can be safely used to strip ammonia from the system to achieve the highest ammonia removal possible without affecting the microbial population. This approach was not discussed in the literature, however, Yin et al. (2019) tested the ammonia-stripping during hydrolysis using biogas under hyper-thermophilic conditions and established the proof-of-concept. The objective of this study was to evaluate the enhancement in methane production due to post-hydrolysis ammonia-stripping of poultry manure at two temperatures (40 and 55 ^{o}C).

Materials and methods

Poultry manure samples were collected from a farm in Ottawa region, Canada. Samples were characterized for pH, total ammonia nitrogen (TAN), total and soluble chemical oxygen demand (COD and sCOD), total volatile fatty acids (VFA), total alkalinity, and total and volatile solids (TS and VS). The inoculum used in the biochemical methane potential (BMP) test was collected from an outlet of an anaerobic digester running on cow manure and corn silage.

Poultry manure was diluted from 26 to 10% TS to facilitate hydrolysis and flow of air through the sample. The diluted samples were anaerobically incubated for six days at a temperature of 40 ^{o}C, TAN levels were monitored on a daily basis. Part of the hydrolyzed samples was used directly in the BMP test, and the rest was prepared for ammonia-stripping. The conditions of ammonia-stripping relied on the fundamentals of ammonia volatility, pH and temperature were increased to increase the volatility of ammonia. pH was adjusted to 10 using lime ($Ca(OH)_2$) and two temperatures were considered (40 and 55 ^{o}C). The ammonia-stripping bottles were put in a water bath throughout the stripping duration. Airflow at 300 L air/L sample/ hour was inserted through a flexible tube inserted to the bottom of the sample with an aquarium stone attached to the outlet to diffuse the air. Airflow remained for six continuous hours, ammonia and pH were measured every two hours to evaluate the ammonia removal rate.

Raw (untreated), hydrolyzed, and ammonia-stripped samples were inoculated on a VS_s/VS_i ratio of 0.5 to 1 and anaerobically incubated at a temperature of 37 ^{o}C and shaking speed of 100 rpm for 25 days. Biogas production was measured daily using water displacement in monometer, and methane content was determined weekly using Gas Chromatography. Digestate inside the BMP bottles were characterized similarly to the initial characterization.

Results and discussion

Ammonia-stripping at temperatures of 40 and 55 ^{o}C and pH of 10 led to 70.3 and 79.2% TAN removal. Most of the removal occurred during the first two hours of aeration and removal efficiency dropped afterwards. The decline of the removal efficiency was a result of the pH drop that led most of the ammonia nitrogen to be in the ionic form (NH_4^+). pH dropped because when NH_3 is removed from the sample, hydrogen ions are released due to the

NH_3/NH_4^+ equilibrium kinetics. Figure 1a and 1b shows the results of ammonia removal and pH during the stripping process.

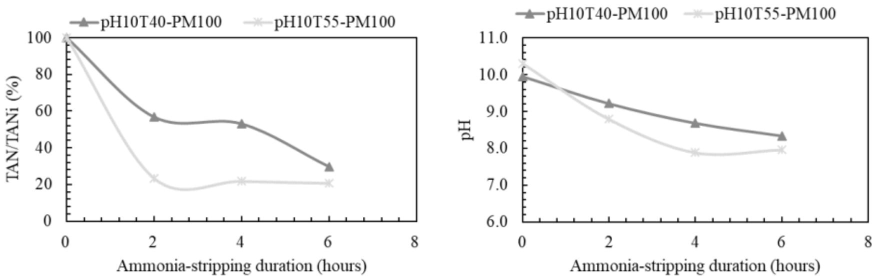

Figure 1: Ammonia removal efficiency and pH during ammonia-stripping.

The results of this experiment showed that ammonia-stripping of poultry manure under the tested scenarios alleviated the ammonia-inhibition effect and allowed the mono-digestion of poultry manure. Untreated and hydrolyzed samples had BMP of 153 and 188 ml CH_4/g VS added, respectively and were inhibited by high ammonia levels that averaged 3300 mg TAN/L. Figure 2 shows the cumulative methane production of all tested samples. No significant lag time was noticed in all samples including the untreated and hydrolyzed samples. The improvement of methane potential due to hydrolysis alone can be explained by the enhanced biodegradability of organic matter by the effect of the hydrolytic enzymes which broke part of the complex carbohydrates, lipids, and proteins into simpler compounds.

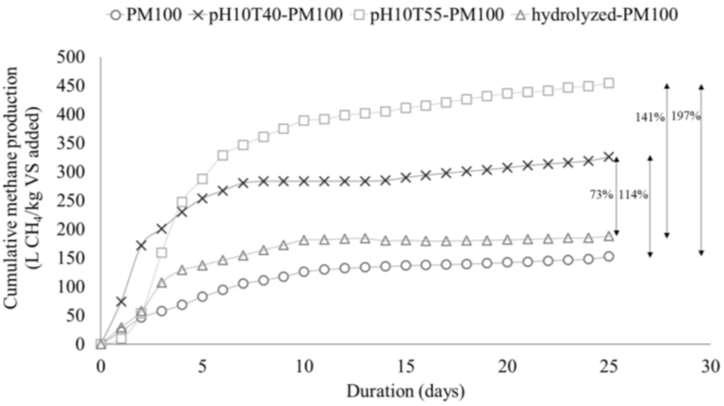

Figure 2: Cumulative biomethane potential of untreated, hydrolyzed, and ammonia-stripped poultry manure.

Ammonia-stripped samples limited the increase in TAN during the BMP to around 2300 mg TAN/L. This concentration of ammonia did not inhibit the methanogens activities as ammonia-stripped poultry manure at temperature 40 and 55 °C improved methane potential by 113 and 197% (compared with untreated samples) and 71 and 141% (compared to hydrolyzed samples), respectively. The results of this study showed that the temperature set during ammonia-stripping had a minor effect on ammonia-stripping but a significant effect on methane production. This is because exposure to high temperatures during the ammonia-stripping led to increasing the solubility and biodegradation of the organic compounds to simpler organic matters that methanogenic microorganism can digest easily. The thermal treatment contributed to around 39% of the methane improvement, while the remaining 61% was due to ammonia removal.

Conclusion

The feasibility of post-hydrolysis ammonia-stripping of AD feedstock was investigated. The results showed that the methane production of poultry manure was significantly enhanced (73-197%) due to ammonia removal. The study showed that the temperature at which the ammonia-stripping is conducted did not significantly affect the ammonia-removal efficiency but significantly improved methane potential.

References

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