Ammonia Removal by Membrane Separator and Air Stripping

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Executive Summary

Purpose of this study is to remove/recovery ammonia from chicken manure digestate (that has high ammonia concentration) ant to determine which method can be integrated for anaerobic digestion process by tubular, hallowfiber membranes and head space flushing experiments.
Conditions of the system were arranged as mesophilic so the results could be applicable in real anaerobic membrane operation systems. Ammonia removal performance of the membranes were investigated depending on the membrane types, flow rate and concentration of receiving solution. Head space flushing experiments were investigated depending on gas flow rate, strirer rate and carier gas.

Ammonia Removal by membrane

Ultimate goal is to integrate the tested membranes into anaerobic digester.
Hydrophobic membranes were used which these were hollow fiber PP membrane and tubular PP memrane.

Hollow fiber PP membrane

Figure : Preparation of the hydrophobic hollow fiber membrane (HFM) module

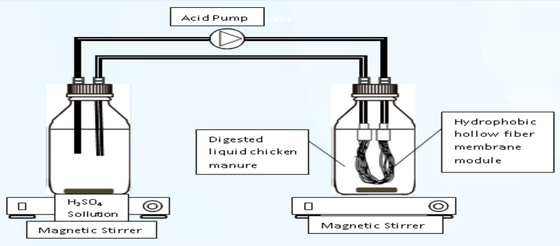

Figure : Setup used in batch experiment with Hollow fiber PP membrane

The HFM experiment was performed continuously passing the H_2SO_4 solution from the HFM module immersed completely below the liquid level in 1.5 L fermented liquid product mixed with magnetic stirrer.During the experiment, samples of both liquid fermented product and H_2SO_4 solution were taken at regular intervals and pH and TAN analyzes were performed.
In HFM experiment;
Temperature of liquid fermentated product, temperature of acid sollution and pH value were stable.
Only the acid solution flow was changed that was passed throught the hollow fiber membranes and the effect of the increasing flow on ammonia separation and removal process was investigated.

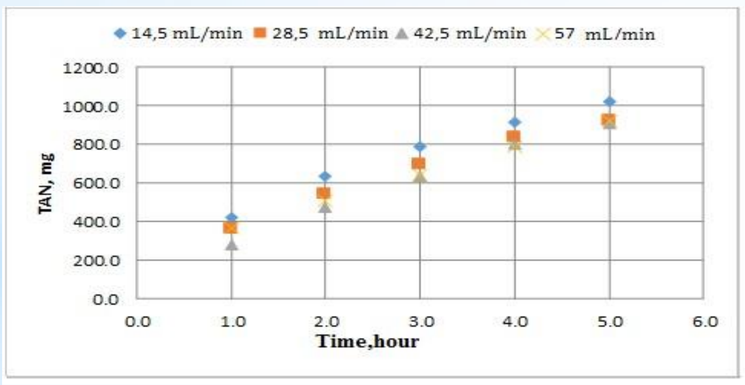

Figure : Effect of acid solution flowrate on removal of ammonia with Hollow Fiber PP membrane.

Removal efficiency was not increase by increasing the flowrate of the acid solution which passed through the hollowfiber membrane. Average flux of PP hollowfiber membrane calculated as 1,34±0,08 gTAN/m^2/hr

Tubular PP Memrane

Figure : Preparation of tubular PP membrane

Figure : The photograph of the setup used in batch experiment with using tubular PP membrane

1.5 L of liquid fermented product which was continuously mixed with a magnetic stirrer. The temperature of the liquid fermented product heated with the help of a heating coiland connected to a digital temperature control unit was kept constant at 36 ± 1 ° C throughout the experiment.Sulfuric acid solution was continuously passed through the tubular membrane using a peristaltic pump as in the HFM experiments. The temperature of the sulfuric acid solution is adjusted with a temperature controlled water bath.

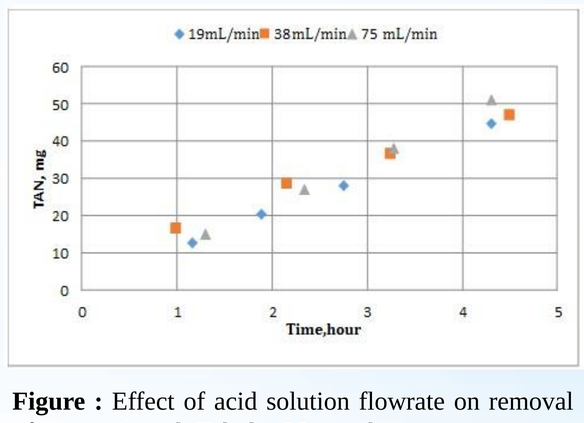

Figure : Effect of acid solution flowrate on removal of ammonia with Tubular PP membrane

Removal efficiency was not increase by increasing the flowrate of the acid solution Result of average flux of tubular membrane calculated as 1,42±0,04 g TAN/ m^2/ hr and result of average flux of tubular membrane just a little bit bigger than result of hollowfiber.

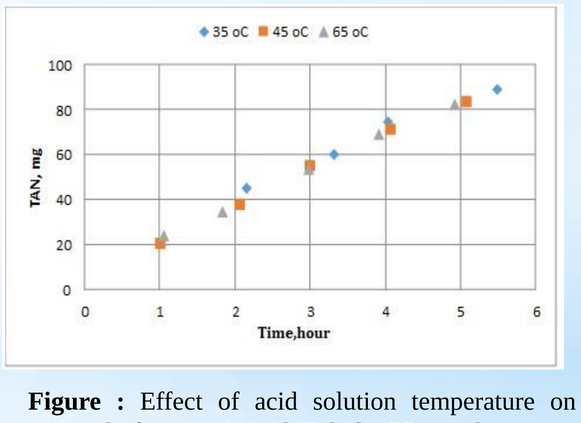

Figure : Effect of acid solution temperature on removal of ammonia with Tubular PP membrane

The effects of the temperature of acid solution on the ammonia removal efficiency were analyzed. Experiments made with 3 different temperature (35, 45, 65ºC) and constant flowrate (45mL/ min) of acid solutions was used. Increasing temperature of the acid solution doesn't has any effect on ammonia removal efficiency of tubular membrane.

Ammonia Stripping Experiments

Ammonia stripping experiments were performed in two different ways, applying gas to the below the liquid level by diffusors (classical) or the surface by head space flushing and ammonia removal efficiency was observed in these experiments.

Air Striping

Liquid fermented product has high ammonia concentration, high alkalinity and also has some volatile fatty acids (VFA), so it caused serious foaming problems. It was determined from obtained results and literature that even if biogas was used, ventilation with diffusor process cause excessive foaming problem and that is not acceptable for integrated usage.

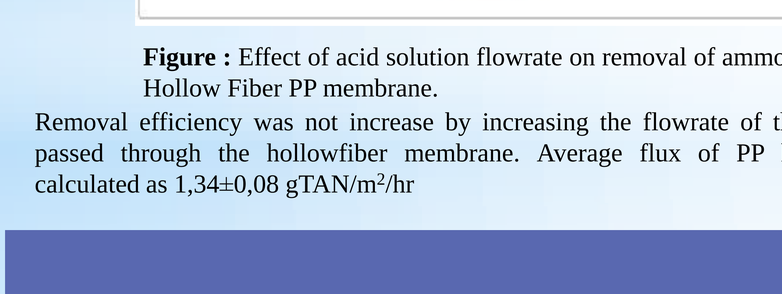

Figure : Foaming problem in ammonia stripping process that includes ventilation with diffusor.

Head Space Flushing Experiments

The carrier gas (air/biogas) was introduced to the surface of liquid in head space flushing to prevent foaming problem. Liquid fermented product was mixed continuously by magnetic stirrer to remove ammonia easily from surface while carrier gas was introducing to the system. When ammonia was stripped from the surface, carbon dioxide which increases the pH is also captured by CO_2 trap.

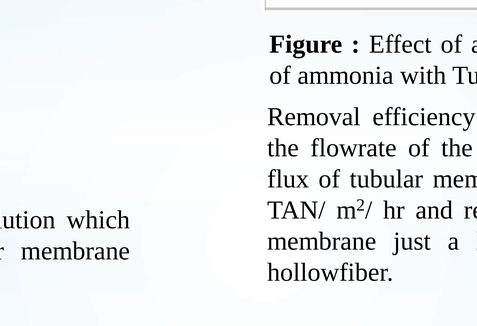

Figure : Time-dependent TAN removal amount of head space flushing experiment

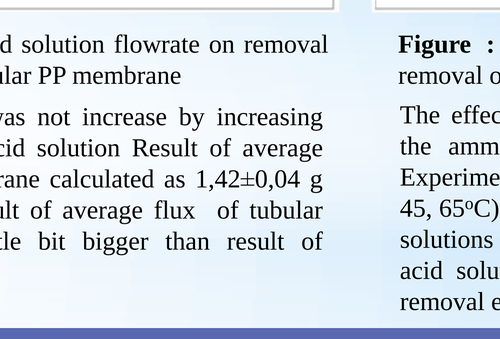

Figure : TAN removal rates of head space flushing experiments.

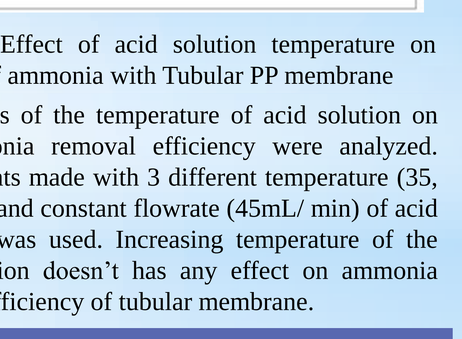

Figure : Time dependent pH change in head space flushing experiments.

	Carrier Gas	CO_2 Removal	Gas Flowrate (ml/min)	Stirring Rate (RPM)	TAN removal rate (mg TAN/ hr)
Experiment-1	Air		3300	1100	84
Experiment-2	Air		880	1100	61
Experiment-3	Biogas	Yes	880	1100	57
Experiment-4	Biogas	Yes	880	240	28
Experiment-5	Biogas		880	1100	9

Figure : Summary result table for head space flusshing experiments.

it is very hard to apply high stirrer rate in an anaerobic digester that has 5-8% solid or in a sludge line. Also external alkali addition or removal of CO_2 is very crucial to increase pH. So ıt is not probable to integrate ammonia removal with head space flushing process in to anaerobic digesters.

Conclusion

The purpose of the project was to determine ammonia removal/recovery methods which can be integrated for anaerobic digestion process. Foaming problem was observed in air stripping experiments and this problem was prevented with head space flushing method but high stirrer rate was needed to obtain efficient ammonia removal and it is not probable to obtain that stirrer rate in an anaerobic digester. So it is very hard to integrate head space flushing method into an anaerobic digester.
It is considered that tubular and holowfiber membranes can be integrated in an anaerobic digester to remove/recover ammonia.