Task 1.1 - Disintegration-based methane enhancement by side-stream vacuum stripping

Objective

The objective was to evaluate the effect of vacuum stripping on ammonia removal and disintegration of chicken manure digestate at different pH values (8.5, 9.5, and 10.5) and temperatures (30, 50, and 70 °C). Thus, it was investigated that, how much the biogas potential of nitrogen rich chicken manure could be increased by vacuum stripping if the vacuum-stripped digestate is recirculated to the anaerobic digester.

Set-up/Parameters

Batch vacuum stripping tests were carried out using a 1-L airtight, vacuum-resisted glass vessel connected to a vacuum pump. The temperature of the vacuum vessel was controlled with a heating jacket connected to a digital temperature controller. The digestate was mixed with a magnetic stirrer and the vacuum pressure was monitored by means of a manometer during the tests. The vacuum stripping test setup is shown in Figure 1.

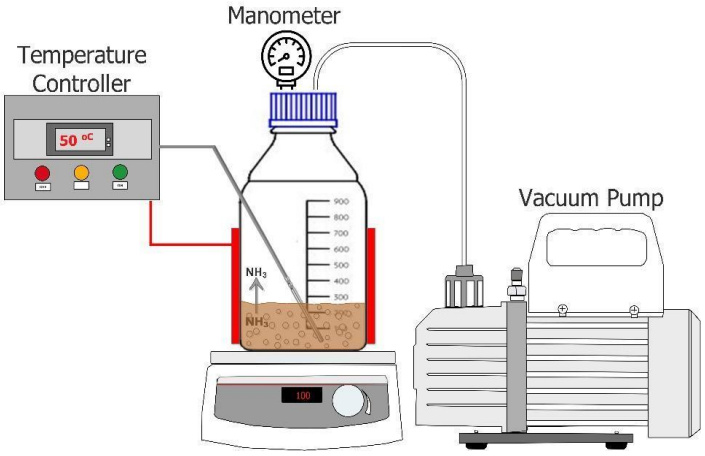

Figure 1: Batch vacuum stripping test set-up.

In vacuum experiments, two different retention times (120 and 30 min) were tested in order to evaluate the effects of vacuum duration on ammonia removal and disintegration of digestate (increase in soluble COD). In addition, the effects of temperature (35, 50, and 70 °C) and pH (8.5-9.5-10.5) were also assessed in 120-min vacuum experiments. 30-min experiments were only performed at 50, and 70 °C.

To investigate the effect of vacuum stripping on residual biomethane potential, BMP tests were carried out with 30-min vacuum-stripped and non-stripped digestate. Although 120 min-vacuum stripping was found to be more effective than 30 min stripping in terms of ammonia removal and disintegration of organic matter, 120-min vacuum-stripped digestates were not used in BMP tests due to economic concerns.

BMP tests were carried out in 500 ml glass bottles with 400 ml active volume in duplicate under mesophilic conditions (36±1 ℃). Test bottles were continuously stirred on an orbital shaker placed in an incubator.

Results

120-min-test results are given in Table 1. Results show that the increase in sCOD, which is an indication of disintegration, is very low at temperatures lower than 70 °C. In addition, we determined that pH was as effective as temperature on disintegration in vacuum experiments and sCOD increased considerably at higher temperature and pH values. However, in the tested ranges, high temperature and pH values individually are not very effective. For instance, at 70 °C, the increase in sCOD concentration is negligible at pH 8.4. The disintegration efficiency and TAN removal were 85.5%±0.2 and 94.3±0.8%, respectively at 70℃ and pH=10.5 at 120-min stripping tests. Experimental results showed that increasing pH and temperature significantly increase TAN removal, but pH is more effective.

Table 1: Results of 120 minutes batch vacuum tests.

Temperature (℃)	pH	Evaporation (%)	Disintegration efficiency (%)	TAN removal (%)
35	8.3 ± 0.1	11.3 ± 3.6	7.3 ± 1.7	18.5 ± 7.9
	9.5 ± 0.1	11.6 ± 1.9	<5	32.7 ± 0.3
	10.5 ± 0.1	12.5 ± 4.1	10.6 ± 6.6	67.4 ± 0.2
50	8.5 ± 0.1	19.5 ± 7.7	<5	47.8 ± 7.2
	9.5 ± 0.1	36.2 ± 1.4	<5	87.8 ± 3.2
	10.5 ± 0.1	29.7 ± 10.8	8.9 ± 2.0	90.9 ± 6.4
70	8.4 ± 0.1	69.6 ± 1.9	<5	93.3 ± 3.3
	9.5 ± 0.1	67.3 ± 10.7	54.2 ± 5.9	97.5 ± 0.2
	10.5 ± 0.1	69.1± 9.3	85.5 ±0.2	94.3 ± 0.8

Due to the high loss of water and energy by evaporation in the 120-min vacuum experiments, new 30-min vacuum stripping experiments were carried out to obtain the digestate to be used in the BMP test. Since 35 °C is ineffective in both disintegration and TAN removal, the 30-min vacuum experiments were carried out at 50 and 70 °C and at pH 8, 9.5, and 10.5. As seen in Table 2, disintegration efficiency and TAN removal were 39.2±2.6% and 67.0±1.3%, respectively at 70 °C and pH 10.5. Although results were relatively lower than 120-min experiments, the increase in sCOD was about 40% at 70 °C and pH 10.5.

The results showed that the increase in sCOD especially at 70 °C and pH 9.5 and 10.5 did not clearly reflect in BMP test results. Although the 39.2±2.6% increase in sCOD of the vacuum stripped digestate at pH 10.5 was significantly higher than that of the stripped digestate at pH 8 and 9.5, the biomethane potential was surprisingly detected below that of other digestates, even the control set. This result is attributed to the inhibition of methane production by sodium, which was added as NaOH to adjust the pH to 9.5 and 10.5 in vacuum stripping experiments.

Table 2: Results of 30 minutes batch vacuum tests.

Temperature (°C)	pH	Evaporation (%)	Disintegration efficiency (%)	TAN removal (%)
50	7.9 ± 0.1	6.8 ± 0.9	7.5 ± 2.9	20.5 ± 0.9
	9.5 ± 0.1	7.8 ± 1.3	15.5 ± 1.1	58.9 ± 5.2
	10.5 ± 0.1	5.4 ± 1.1	16.2 ± 2.2	56.3 ± 11.7
70	8.0 ± 0.1	6.4 ± 2.2	5.8 ± 2.4	38.8 ± 3.7
	9.5 ± 0.1	10.6 ± 0.8	14.4 ± 4.3	64.8 ± 5.6
	10.5 ± 0.1	6.6± 0.9	39.2 ± 2.6	67.0 ± 1.3

Table 3: BMP tests and methane production yields.

Temperature (°C)	Vacuum Stripping pH	BMP test pH	Disintegration efficiency (%)	NH_4-N (mg/l)	CH_4 yield (mL CH_4/gVS)	Increase in CH_4 yield (%)	NaOH (g/L)
Control	-	8.00		3578	37.8 ± 2.0	-	
50	7.9 ± 0.1	8.07	7.5 ± 2.9	3366	47.7 ± 4.0	26.2	
	9.5 ± 0.1	7.99	15.5 ± 1.1	2580	52.3 ± 11.8	38.4	5.4
	10.5 ± 0.1	7.99	16.2 ± 2.2	2508	36.9 ± 3.0	-	8.7
70	8.0 ± 0.1	8.05	5.8 ± 2.4	3006	56.2 ± 29.7	48.7	
	9.5 ± 0.1	8.00	14.4 ± 4.3	2294	30.0 ± 0.6	-	6.5
	10.5 ± 0.1	8.00	39.2 ± 2.6	2450	42.5 ± 3.4	12.4	8.9

Conclusions/Remarks

- The highest disintegration and TAN removal were achieved at 70 °C and pH=10.5 with 120-min vacuum stripping and were 85.5%±0.2 and 94.3±0.8%, respectively.
- Excessive evaporation resulting in high energy loss caused 120-min vacuum stripping to be cost inefficient above 55 °C.
- In 30-min vacuum stripping water lost due to evaporation decreased significantly and acceptable TAN removal (71.1%) and disintegration efficiency (45.9%) were achieved.
- The highest residual biomethane potential, which was 48.7% more than that of the control set was obtained with 30-min vacuum stripping at 70 °C without pH adjustment.
- The optimum conditions obtained through batch experiments will be validated in Task 2.2 using a vacuum stripper operated on the internal recirculation line of a daily-fed laboratory scale anaerobic digester.

BioDEN

A biorefinery approach to exploit digestate as key feedstock in the energy – nutrient nexus

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More information about the project: check out the project website.
Project partners: Biogas-E, KU Leuven, Ghent University, Marmara University, VCM, OSTIM

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