Effects of vacuum treatment on anaerobic digestion of chicken manure digestate

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1. Introduction

Anaerobic digestion (AD) is a well-known process of converting organic wastes into bioenergy. In order to use the energy potential of organic wastes efficiently, several pre/post treatment techniques have been tested so far (Kor-Bicakci and Eskicioglu 2019). In this study, we aimed to increase the overall biogas yield during subsequent digestion of the vacuum-stripped digestate by stripping ammonia and increasing disintegration of organic materials. In this scope, a novel vacuum treatment technique was applied to digestate and its effects on disintegration and ammonia stripping were investigated. This technique is based on decreasing the pressure at a level that the digestate can boil at low temperatures (Silberberg 2009). It was hypothesized that; boiling action may help the disintegration of slowly biodegradable organic matter present in the digestate and strip ammonia (Ukwuani and Tao 2016). The disintegration of organic matter may lead to an increase in biogas yield whereas stripping of ammonia reduces the ammonia inhibition risk (Bayrakdar et al. 2017). In the tests, chicken manure (CM) was used as the source of organic matter and the vacuum stripping tests were applied to CM digestate.

2. Material and Methods

2.1 Batch vacuum tests

Batch vacuum tests were carried out using digestate in a 1 L airtight, vacuum-resisted glass bottle. The digestate was obtained from a full-scale anaerobic chicken manure digester in Afyon, Türkiye. Optimum conditions for both disintegration and ammonia removal were determined with different temperatures (35-50-70℃), and pH (8.5-9.5-10.5) values while boiling the samples under negative pressure. Each vacuum stripping test was performed for 30 minutes. Disintegration efficiency was evaluated by the increase in the concentration of soluble chemical oxygen demand (sCOD) during the test period. Water loss due to evaporation and the total ammonia nitrogen (TAN) removal performance were determined for each experiment.

2.2 Biomethane Potential (BMP) Tests

To investigate the effect of vacuum treatment on biogas production efficiency, BMP tests were carried out with raw and vacuum-treated digestate. The BMP tests were performed for the digestate subjected to vacuum treatment at 50 ℃ and 70℃, where the highest sCOD increase was obtained. BMP tests were carried out in 500 ml glass bottles with 400 ml active volume under mesophilic conditions (36+/-1 ℃) and the test bottles were continuously agitated on an orbital shaker. The digestate used in BMP tests was the same as explained in vacuum test applications and the inoculum was taken from an ongoing laboratory scale anaerobic digester fed with CM. The inoculum was added to each BMP bottle with an inoculum to digestate ratio of 1:1, by volume.

Biogas produced in test bottles were collected in gas bags and periodically measured by the water displacement method. The composition of the biogas was also determined by a gas chromatograph with a thermal conductivity detector (Shimadzu GC-TCD, Japan).

3. Results and Discussion

3.1 Results of batch vacuum tests

The conditions applied in batch vacuum tests and the results obtained are summarized in Table 1. The table shows that the efficiency of disintegration increased significantly at 70 ℃ in vacuum experiments. It was determined that TAN removal increased with increasing pH and temperature, but it was most affected by pH. At the optimum conditions (70℃ and pH=10.5), sCOD increase and TAN removal were calculated to be 39.2±2.6% and 67.0±1.3%, respectively.

Table 1 Results of batch vacuum tests

Temperature, ℃	pH	Evaporation, %	COD increase, %	TAN removal, %
35	8.0 ± 0.1	3.9 ± 0.8	<1.0	<1.0
	9.5 ± 0.1	4.4 ±0.4		12.2 ± 4.7
	10.5 ± 0.1	3.0 ± 1.8		43.0 ± 1.7

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

*The values given in the table show the mean and standard deviation of the measurements.

3.2 Results of BMP Tests

Conditions of BMP tests and the obtained results are presented in Table 2.

Table 2 BMP Test and methane production yields

Temperature ,°C	Pressure (kPa)	Vacuum Application pH	BMP test pH	NH_4-N (mg/l)	CH_4 yield (mL CH_4/gVS)	Increase in CH_4 yield (%)
Control	-	-	8.00	3578	37.8 ± 2.0	-
50	8.1±0.7	7.9 ± 0.1	8.07	3366	47.7 ± 4.0	26.2
	8.5±1.1	9.5 ± 0.1	7.99	2580	52.3 ± 11.8	38.4
	8.5±0.9	10.5 ± 0.1	7.99	2508	36.9 ± 3.0	-
70	24.5±0.9	8.0 ± 0.1	8.05	3006	56.2 ± 29.7	48.7
	23.8±2.5	9.5 ± 0.1	8.00	2294	30.0 ± 0.6	-
	25.2±1.1	10.5 ± 0.1	8.00	2450	42.5 ± 3.4	12.4

The highest biogas production efficiency was obtained with the BMP test subjected to vacuum treatment at 70℃ without pH adjustment and 48.7% more biogas was produced compared to the control set. In this set, the TAN value was only 16% lower than the control but about 50% more CH_4 was produced. This indicates that during the vacuum treatment, the CH_4 potential of the digestate increased as a result of disintegration. However, methane yields in the vacuum application pH at 10.5 where the higher sCOD increase and TAN removal were obtained, were the lowest compared to pH 8 and pH 9.5. This situation can be attributed to inhibition by sodium ions in NaOH used to raise the pH in vacuum experiments.

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