ANAEROBIC CHICKEN MANURE DIGESTION COUPLED WITH AMMONIA SEPARATION

Department of Environmental Engineering, Marmara University
ENVE498 Graduation Project

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OBJECTIVES

The goal of this study is to be able **to digest raw chicken wastes** containing approximately 25% TS by increasing the organic loading rate to 5 - 5.5 kg-VS/m³.day **without any dilution** or **using very little dilution water** and to **obtain maximum biogas production efficiency** under these conditions. Therefore, **the need of digester volume** is decreased and also **the methane production per unit volume of digester** is increased due to high organic loading rate.

INTRODUCTION

- In anaerobic digesters, **ammonia** is the product of the hydrolysis of organic nitrogen.
- **Ammonia** is an important source of alkalinity. However, it is an inhibitory compound for methanogens when it reaches to high levels and as a result, it adversely affects **biogas production**.
- Ammonium nitrogen exists in two forms**: Ammonium ion** (NH_4^+, below pH 7) and **free ammonia** (NH_3, above pH 7).
- Chicken waste is rich in **nitrogen content**. Therefore, risk of ammonia inhibition is high.
- In order to prevent ammonia inhibition during anaerobic digestion of chicken wastes, other than continuous ammonia removal, the most common applications in the literature are **dilution of wastes** and **co-digestion with other wastes**.
- Since the aim of this project is increasing **the OLR and the efficiency of methane production** from chicken wastes, digestion of chicken wastes was performed as single digestion. The risk of inhibition was kept under control by **using PP** (polypropylene) **gas-permeable membrane**.

MATERIAL AND METHODS

Two glass bioreactors with a total volume of 6 L and an active volume of 5 L and operated in parallel were used **to digest chicken manure** in anaerobic continuously stirred tank reactors (CSTRs) and to study biogas production. One of these reactors was placed with **hollow fiber** firstly, followed **by a tubular hydrophobic PP membrane** to remove the ammonia in the liquid phase (CSTR-M). The other reactor was operated for control purposes without membrane under the same conditions (CSTR-C).

The CSTRs, which are **fed once daily**, are continuously mixed with a mechanical stirrer and kept at **36 ± 1°C** with a digital temperature-controlled heating band. The hydraulic retention time (HRT) was kept constant for 30 days throughout the study. The CSTRs were operated for 255 days with gradually **increasing the organic loading rates** (OLR) and hence **the input TAN concentrations**.

To control the process, certain types of experiments were made in this study. The list of the experiments include the determination of biogas volume (daily), methane percentage in biogas (twice a week), VFA amount (twice a week), total alkalinity, pH (twice a week), TS and VS (twice a week), TKN (once a week), NH_4-N (twice a week).

Figure [1]: Photograph of CSTR-C and CSTR-M operated under the same conditions

RESULTS AND DISCUSSION

During operation, when the OLR and TKN were **increased**, correspondingly TAN was also i**ncreased**. Both of the reactors were operated **under the same conditions** until ammonia reaches to a certain point.

- **68th day** — If TAN exceeds 5000 mg/L, ammonia inhibition **starts to occur**. So that, PP hollow fiber membrane (HFM) was placed in CSTR-M on 68th day.
- **95th day** — After acid leakage problem occurred on 74th day, PP tubular membrane (0,0184 m²) was placed in CSTR-M on 95th day.
- **100th day** — In both reactor, **trace elements addition**, which are substantial for hydrogen-using methanogens, were started on 100th day. Thus, inhibition of control reactor was delayed for approximately 50 days.
- **126th day** — Ammonia removal became **insufficient** on 126th day due to **increasing OLR and influent TKN** values. So that, surface area of the PP tubular membrane was increased to 0.0292 m².
- **150th day** — **CSTR-C** was completely **inhibited** because of ammonia and methane production was cut off.
- **244th day** — Surface area of PP tubular membrane was once again increased to 0.074 m² **to control inhibition.**
- **255th day** — Even at high OLR values and with very little dilution, ammonia inhibition was kept under control with the help of PP tubular membrane. On 255th day, **the study ended**.

The summarized results are given in Table [1]. The values in the table are written where a **critical change** is present.

Table [1]: The critical values of various parameters depending on time

Day	OLR (kg-VS/m³.day)	TKN influent (mg/L)	TAN in reactor (mg/L)		FAN in reactor (mg/L)		Methane Production (m³/kg-VS)		VFA (mg/L) (Acetic acid and Propionic acid)	
			Membrane	Control	Membrane	Control	Membrane	Control	Membrane	Control
1 - 7	2.75	5780	-	-	-	-	0.05 ± 0.017	0.05 ± 0.017	Over 4700	Over 4700
25	2.75	5780	-	-	-	-	0.31	0.31	Under 200	Under 200
40	3.05	-	-	-	-	-	0.30 ± 0.01	0.30 ± 0.01	-	-
58	3.19	6730	5000	-	-	-	0.30 ± 0.01	0.30 ± 0.01	-	-
69	3.46	7310	-	-	-	-	-	-	-	-
74	-	-	3900	5500		400	0.32	-	500	-
95	-	-	4660	-	Over 400	-	-	0.26	-	6700
109	3.55	-	Over 6900	-	Over 600	-	0.26	0.31	-	-
131	3.80	8840	-	6200	-	550	0.29 ± 0.02	-	-	2100
149	-	-	-	7500	-	730	0.29 ± 0.02	-	-	8000
182	4.00	9160	4200	-	250	-	0.29 ± 0.02	-	330	-
222	4.50	10400	4900	-	360	-	-	-	-	-
242	-	-	Over 5500	-	-	-	0.29 ± 0.02	-	5800	-
244	-	-	-	-	-	-	0.25	-	-	-
255	-	-	3500	-	-	-	0.36	-	900	-

The graphs below were shown with the data obtained throughout the study.

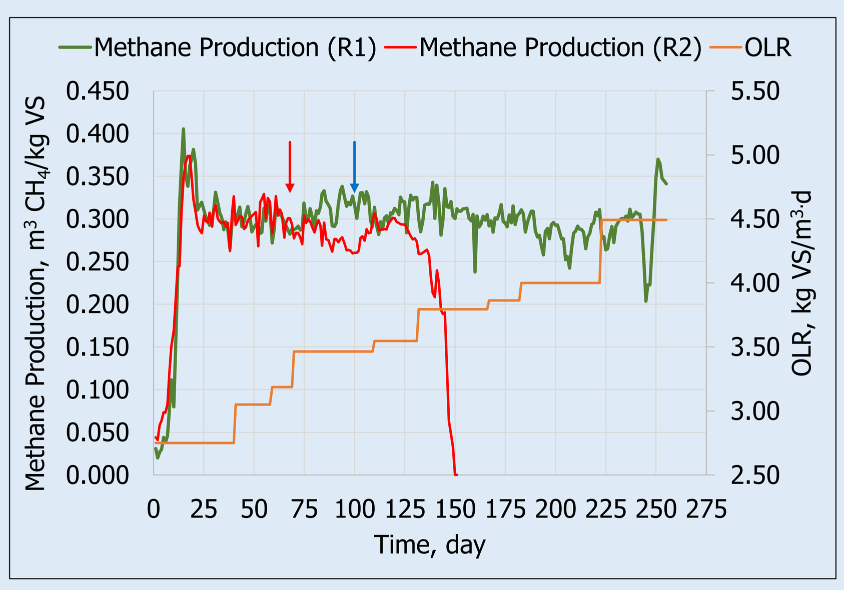

Figure [2]: Methane production and OLR for the both reactors

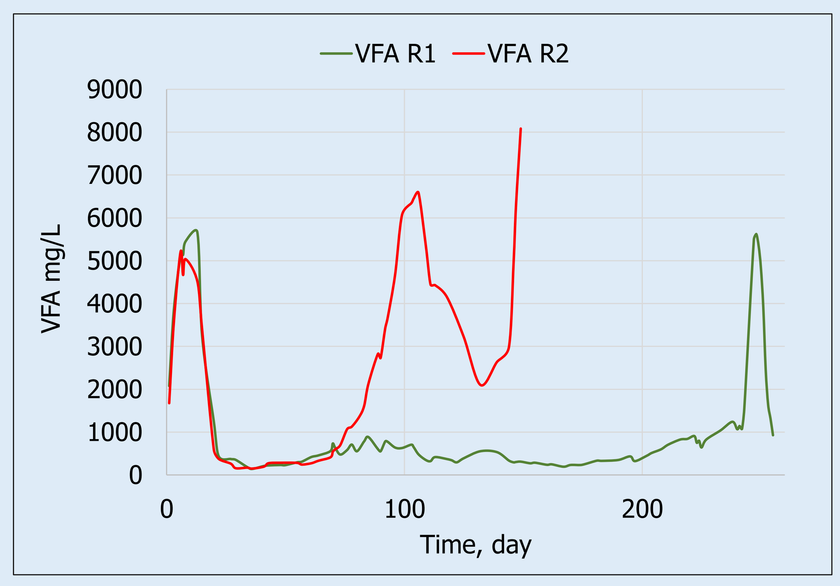

Figure [3]: VFA depending on time

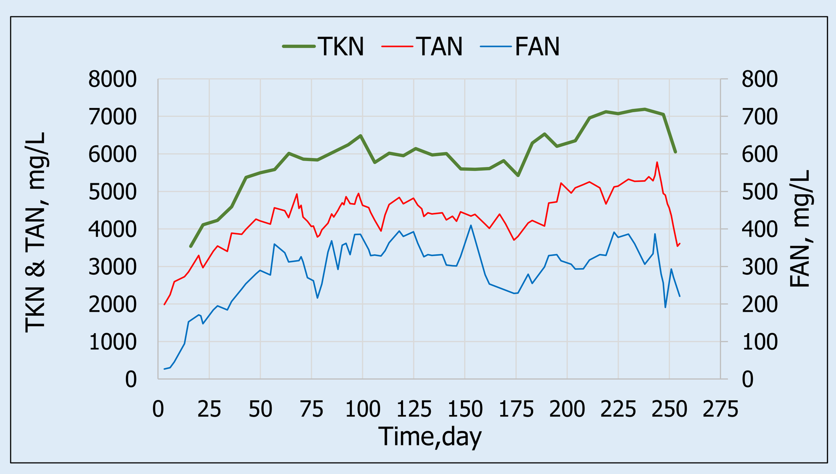

Figure [4]: TKN, TAN and FAN depending on time for R1

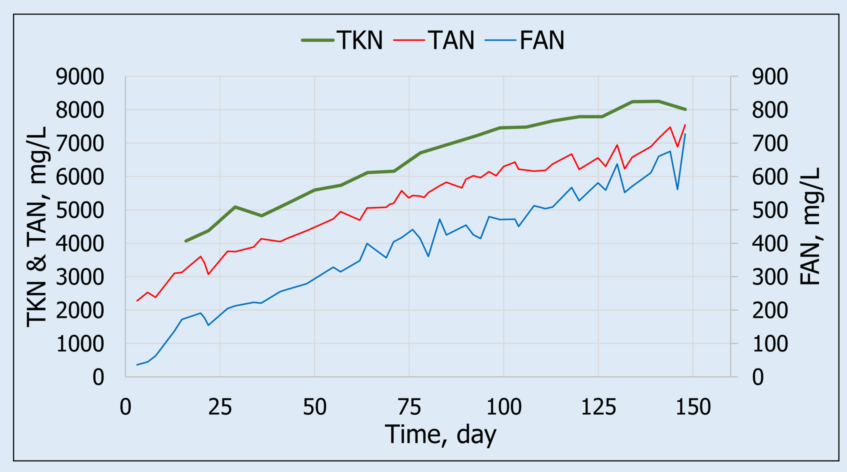

Figure [5]: TKN, TAN and FAN depending on time for R2

CONCLUSION

In this study, **CSTR-M** was operated stably even at OLR of 4.5 kg-VS/m³ with the TAN concentration kept below the inhibition level, **methane production** of 0.31 m³/kg-VS was obtained. These values are well above the values given in the literature for single digestion of chicken wastes. On the other hand, in **CSTR-C operated without membrane insertion**, the TAN concentration exceeded 6500 mg/L by raising the OLR to 3.8 kg-VS/m³ and then, the methane production **was completely stopped within 2 weeks**.

As a result, it has been shown in this study that **biogas can be produced efficiently** from chicken wastes alone without using too much dilution water or mixing with other organic wastes, by **adding the missing trace elements** and **continuously removing ammonia** to keep it under inhibition level with the help of a gas-permeable membrane.