Effects of Various Nitrogen Rates to Biogas Production Yield in Anaerobic Digestion of Only Chicken Manure

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Abstract: High nitrogen content of chicken manure might reach to the degree of toxic effect at anaerobic fermentation system. Raw material nitrogen ratio and the rate of demineralization in the reactor are important parameters in anaerobic reactor design. In this study, effects of various nitrogen contents on biogas production yields were investigated in order to obtain base limits at design phase of biogas plants which will run only chicken manure. All trials were carried out in a continuous stirred-tank reactor (CSTR) at mesophilic conditions. There was no pH adjustment made during trials. The stirrer works at a speed of 20 rpm and they worked every 2 minutes with intervals of 2 min. Reactor loading rate was increased each week in the following sequence 0,5, 1, 2 and 3 g.oDM/l.d. The effect of various nitrogen contents were observed with TKN and NH4-N analysis and also recorded daily biogas production yields. As a result, when there was no pH adjustment made, pH went up to alkali side and reached up to 8-8,5 with increasing loading rate. At this stage, nitrogen inhibition started and the biogas production yield was decreased 54% at the loading rate was as high as 3 g.oDM/l.d. Reflection of the trial results that organic nitrogen demineralization rate should be assumed around 60-70% at stabilize biogas production yield conditions.
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Key words: Chicken manure, Biogas, Nitrogen Inhibition

1. Introduction

Chicken breeding activities are carried out widely among livestock activities in Turkey. In whole country, approximately 164 million units broiler chicken and 71 million laying hens are grown. Chicken production facilities are not spread across the country, but rather they are concentrated in some regions. Breeding activities at regions of Western Black Sea, Marmara and Aegean regions Bolu, Sakarya, Kocaeli, Çanakkale, Balıkesir, Bursa and Afyon has cover a large proportion of the country's whole potential. Chicken manure wastes that also create environmental problems are concentrated in these regions (Kaya, 2009).

Chicken manure, resulting from poultry farming activities, is creating a big problem from an environmental point of view. Environmental problems posed by chicken manure can be listed as odor, flies formation, soil and water contamination. The formation of odors and flies has impacts to the quality of life in residential areas close to the plant and inconvenience to the people living in this region. Moreover, the organic fractions which cannot be stabilized within chicken manure can lead to soil poisoning through uncontrolled decomposing.

On the other side, when the chicken manure stored with an uncontrolled way in the nature freely, it will be washed with rainwater, then groundwater nitrate contamination can occur. Besides all, the ammonia mix with air due to self-composting and evaporation gives rise to air pollution, too (Baban, 2001, Kaya, 2005).

Chicken production is structured into two different sectors such as broiler chicken production and laying hen. The generated wastes from these two production ways differ from each other due to their features and processes. Base material is used in laying hen production and belt system is used in broiler chicken which wet manure can be collected on daily basis. In laying hen production, generally base material is used and the manure can be collected at every 45 day period.

These process differences of the chicken production also affect the physical and chemical structure of poultry manure. Usage base material in laying hens and continuously ventilating system makes the manure more drier comparing with broiler chicken's manure. While the dry matter content of the laying hen is at 25-35 %, this ratio for broiler chicken is at 55-70 % (Safley, 1987). Chicken manure's chemical and physical structure must be considered while solving the environmental problems

When eliminating these high organic matter content wastes it can be converted to environmental, social and economic benefits. Biogas plants can be advantageous as organic materials can be decomposed by an anaerobic media. While biogas is produced, raw materials are turn into organic fertilizer as a final product in a biogas plant. However, high nitrogen content of poultry manure can be toxic for anaerobic fermentation systems.

During anaerobic fermentation process, in the structure of the protein nitrogen to ammonium ions dissolved in water and becomes mineralized. Ammonia is in equilibrium with the ammonium ion within the reactor. This equilibrium is dependent on pH and temperature. It is also known that the toxic effects of ammonia are varied with pH and temperature. The biogas yield of chicken manure is around 500 m^3/ton.oDM. This value can decrease according to ammonia rate. The amount of ammonia in the reactor depends on the amount of nitrogen in the raw material and the rate of demineralization.

In this study, it is aimed to obtain demineralization rate of nitrogen to the ammonium at the at stabilize biogas production yield conditions in order to light up to reactor design stage. At the experiments, the amount of formed demineralization and biogas production rates were measured during various nitrogen loading rates.

2. Material And Methods

In this study, waste from laying hens facilities is used. Three different samples were mixed on different days to prepare a sample.

2.1 Analytic Methods

TS, VS, and pH were determined by standard methods (APHA, 1980). Daily biogas production rate and methane content was recorded. Gas production was determined with miligascounter.

Total Kjedhal nitrogen (TKN) and NH4-N were determined by standard methods and was analyzed using automatic Kjeldahl distillation systems. (SM 4500)

2.2 CSTR Trials

15 lt anaerobic fermenters were used in this study. Drawing of these fermenters are given at Figure 1. Fermenters are able to work on both batch and continue running. Temperature inside the fermenter is controlled and required temperature level can be obtained by automation control. There is a mixer inside the fermenter which can be controlled by a driver. A gas flow meter measures the biogas yield and the produced biogas is stored in a gas bags.

Trials were carried with continuous feeding methodology. Inoculation liquid was taken from an active fermenter running on big cattle manure. 10 % inoculation material was added to the fermenter. Reactor was filled 10 l, so hydraulic retention time (HRT) was minimum 60 days. Samples from the beginning and at the end of the trials were analyzed for dry matter (DM), organic dry matter (ODM), pH, total Kjedhal nitrogen (TKN) and ammonium (NH4-N).

Mesophilic conditions at 38 ^oC were fixed during trials. The stirrer works at a speed of 20 rpm. They worked every 2 minutes with intervals of 2 min. Trials were started with 0,5 g.oDM/l.d. This value was increased each 3 weeks' time as 1, 2 and 3 g.oDM/l.d. Poultry manure was fed to the fermenter once in a day. Daily feeding amounts were 28,5 g, 57 g, 114 g ve 171 g, respectively.

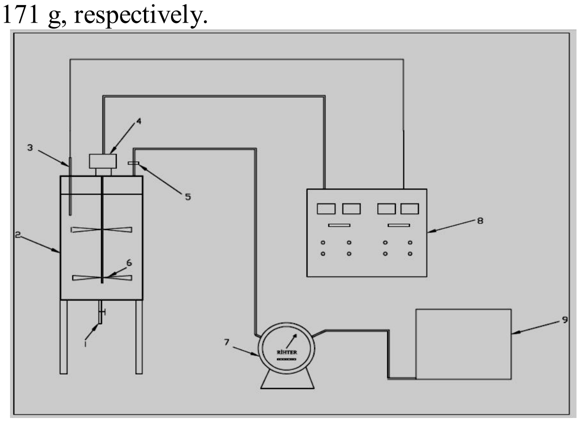

Figure 1. Anaerobic Fermenter: 1. Discharge valve, 2. Fermenter 3. Thermocuple, 4. Mixer engine, 5. Gas relief valve, 6. Mixer, 7. Gas flow meter, 8. Control cabinet, 9. Gas storage

3. Results

The specifications of the chicken manure are presented at Table 1:

Table 1. Chicken manure specifications

DM (%)	oDM (%)	N (%, at DM)
23,86	73,56	8,10

Daily biogas production rates from various feeding rates were presented at Figure 2. The maximum biogas production amount was recorded as 13,4 l. Daily average biogas production rates are as follows:

Table 2. Daily average biogas production rates

Reactor Number	Loading rate (g.oDM/l.d)	Biogas production (l)
D1	0,5	2,73
D2	1	4,70
D3	2	5,78
D4	3	5,67

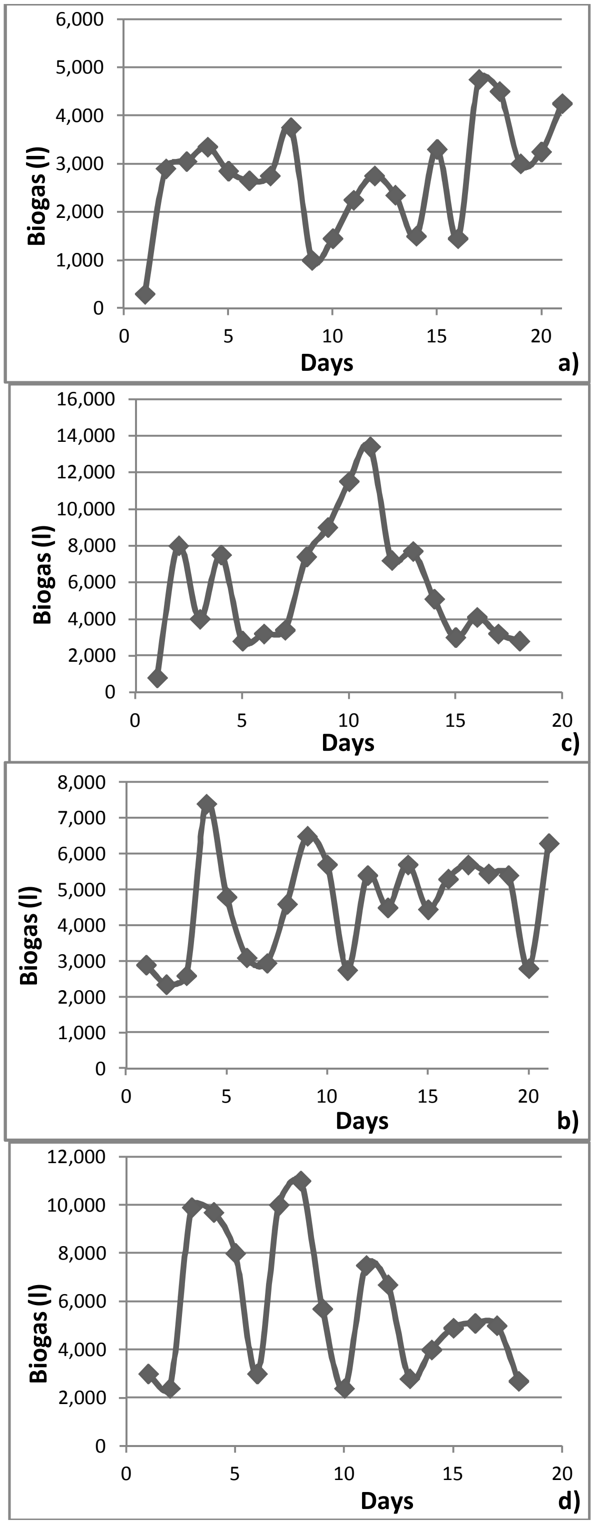

Figure 2. Daily biogas production yield a) Loading rate: 0,5 g.oDM/l.d, b) Loading rate: 1 g.oDM/l.d, c) Loading rate: 2 g.oDM/l.d, d) Loading rate: 3 g.oDM/l.d,

The pH values of measured each day were given at Figure 3. There was no pH adjustment made. Although pH values is required to be 7-7,5 at a continuously running biogas plant, it was measured that the pH was above 7,5 during trials. pH level was higher than 8, when acid production was enough for biogas production. Because of the high ammonia value, the buffering capacity was more than acid formation. This situation causes reduction of biogas production yield.

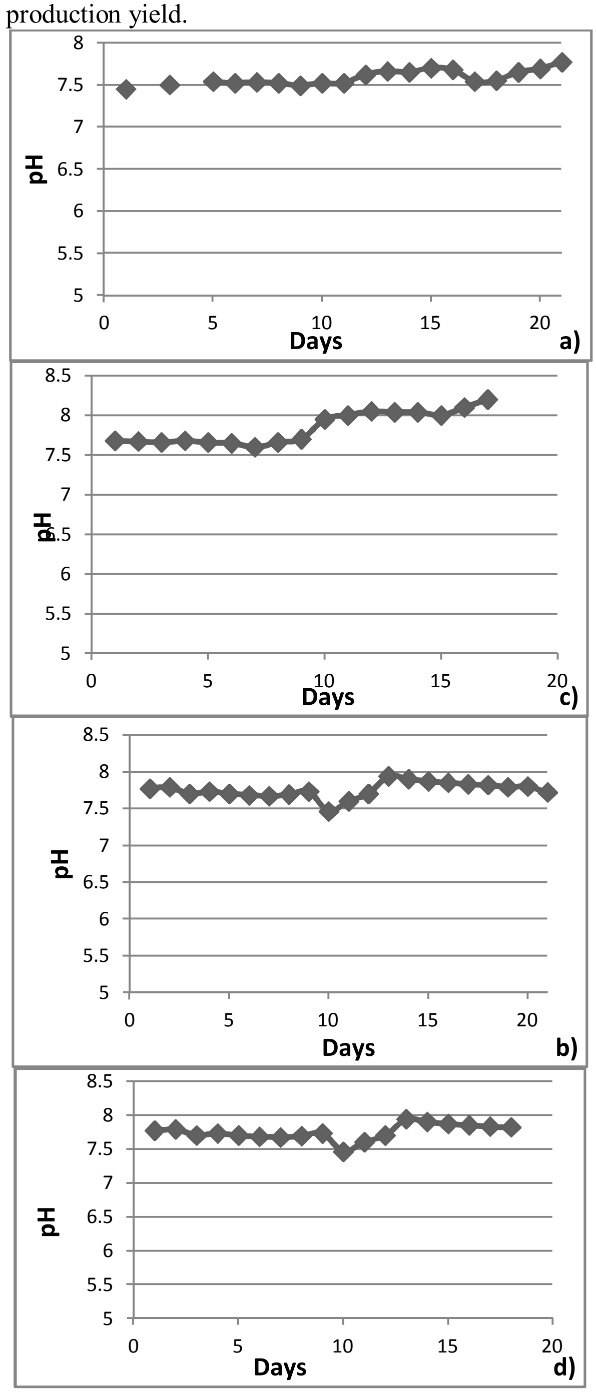

Figure 3. Daily pH amount a) D1, b) D2, c) D3, d) D4

Addition to these results, it was observed that pH value was fluctuating.

When comparing daily biogas production yield per raw materials' dry matter content, it is observed that this amount was decreased by loading rate. Average biogas yields of D1, D2, D3 and D4 were 486,58, 434,73, 272,60, 209,45 ml/g.oDM, respectively. The maximum biogas yield was recorded as 513 ml/g.oDM throughout the trials (Figure 4).

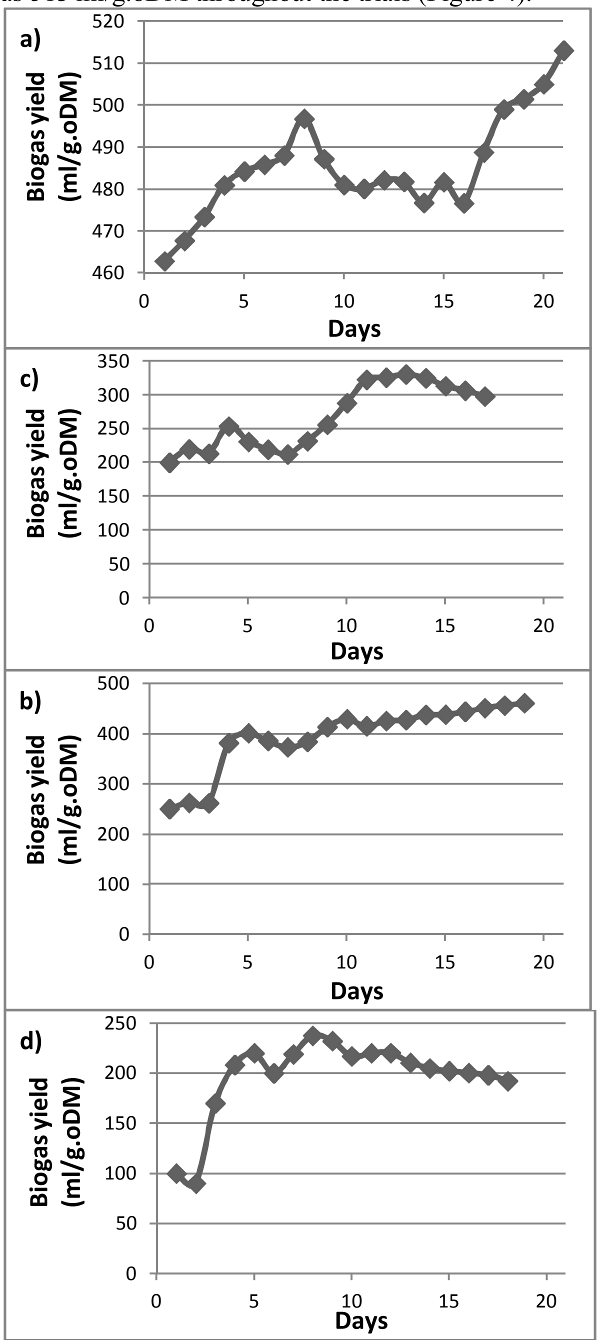

Figure 4. Daily biogas yield (ml/g.oDM) a) D1, b) D2, c) D3, d) D4

TKN and NH4-N analysis were done during each trial. Organic nitrogen content of input chicken manure was 82% as which was taken from literature (Chadwick, 2000). Additionally, The output Norg calculation was found by subtracting NH4-N from TKN.

Biogas yield decreased with increasing conversion of organic nitrogen to the ammonium. Normally, organic nitrogen conversion is desirable when C/N balance is optimum. So, we can assume that inhibition occurs in the reactor because of these biogas yield results. However, microorganisms can adapt high nitrogen values and systems recover itself. We can see that this picture at trial D2. Firstly, biogas yield was decrease, but it was increase at the following days because of adaptation. Moreover, the same situation was observed at the trial D4 although the loading rate was high, the reactor could not be recovered and it was inhibited. It can be said from these results that organic nitrogen demineralization rate should be around 60-70% to have a stabilize biogas production yield.

Table 2. Nitrogen analysis results of the trials

	TKN (mg/l)	NH4-N (mg/l)	Norg (input) (g)	Norg (output) (g)	Norg. *Mine. Rate (%)
D1	2.320	1.780	17,77	5,64	68,28
D2	2.995	2.795	38,90	4,52	88,38
D3	4.875	4.340	90,77	28,20	69,93
D4	6.150	6.100	158,02	9,18	94,19

*Mineralization

4. Evaluation

When only chicken manure used as raw material at the anaerobic digestion and there was no pH adjustment made, pH went up to alkali side and reached up to 8-8,5 with increasing loading rate. At this stage, nitrogen inhibition started and the biogas production yield was decreased 54% at the loading rate was as high as 3 g.oDM/l.d. In conclusion, reflection of the trial results that organic nitrogen demineralization rate should be assumed around 60-70% at stabilize biogas production yield conditions.

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