BIOGAS CONTROLLING SYSTEM TESTING WITH POULTRY FEATHER RECYLING

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ABSTRACT

Feather is produced in large amounts as a waste in poultry slaughterhouses. Only 60-70% of the poultry slaughterhouse products are edible for human being. The high protein content of poultry feather - dried feather contains 91% proteins (Salminen and Rintala 2002) - makes it an excellent raw material for biogas production. The keratin-content of feather difficult to digested, so physical, chemical and/or biological pre-treatment are needed in practice, which have to be set according to the utilization method. Chicken feather waste was enzymatic degraded, and then digested in anaerobic bioreactors in different ratio (0, 5, 7.5 and 10%). Cattle slurry, corn silage and mesophilic digestate was the control without pre-treated feather. The bioreactor system (4 digesters with 6 litre volumes) was controlled by an ACE SCADA software which granted pre-programmed measurement (pH, temperature, mixing, CH_4, CO_2, etc.). The produced biogas flows were filtered. Following the quantity measuring of the biogas, the gas was switched (doubled valve-system). The quality of the gas mixture was monitored continuously with custom created and periodically with MX42A gas-analyser (H_2S, NH_3).
Our main objectives were testing the new biogas controlling system, to determine the methane potential of feather waste and the most effective treatment ratios. Variance analysis with Tukey's test was applied to examine differences between the control and different treatments. Feather waste recycling with anaerobic digestion provides an environmentally friendly way of utilization.

keywords: biogas production, poultry feather, waste recycle

INTRODUCTION

In Hungary, only 10 high-capacity agricultural by-products and waste processing biogas plants were built in the least 10 years. Manure, slurry, plant by-products, energy plants are usually utilized as raw materials, but often is used food industrial by-products and wastes (Al Seadi et al. 2008). Feather is produced in large amounts as waste in poultry slaughterhouses. Only 60-70% of the poultry slaughterhouse products is edible for human (Hegedűs et al. 1998). Dried feather contains 91% protein (Salminen and Rintala 2002), the high protein content of poultry feather makes it an excellent raw material for biogas production. The problem is, that the keratin-content of feather difficult to degraded, so physical, chemical and/or biological pre-treatment are needed in practice, which have to be set according to the utilization method.
The quality and quantity of biogas is being monitored continuously throughout the process. The manufactured, pre-designed and commercially available software are not enough adaptable and their parameterization are not solved. Our main objectives were testing the new biogas controlling system, to determine the methane potential of pre-treated feather waste and the most effective treatment ratios. Quality and quantity of biogas production depend up on the feed stock characteristics (Tada et al. 2005) as well as on the digester operating conditions (Stafford

et al., 1980). In the biogas plant the control and the monitoring are indispensable in case of certain parameters - such as pH, temperature and organic loading rate, mixing and biogas yields. Primary importance operates these parameters in an optimal interval to effectiveness operation of the biogas plant (Yadvika et al. 2004). The recent researches focused on the fermentation process controlling based on Fuzzy logic.

MATERIAL AND METHODS

The anaerobic degradation was examined in the Biodegradation Laboratory of the Institute, who the fermentation areas were 4 stainless steel digester (the volume was 6 l per each) in Incubators. In the incubator were used controlled thermometer probes (Pt100) and ventilators to ensure the optimal conditions (mesophilic: 38°C) *(Figure 1)* (Mézes et al. 2008). In 2010 the Institute's laboratory decided to use a new Compair ACE (Adaptive Control Environment) controlling system for supervising experiments and collect process data for further analysis in a higher level than before and this permit of a knowledge-based process control implementation *(Figure 2).*

Figure 1: Incubators and custom created biogas analyser

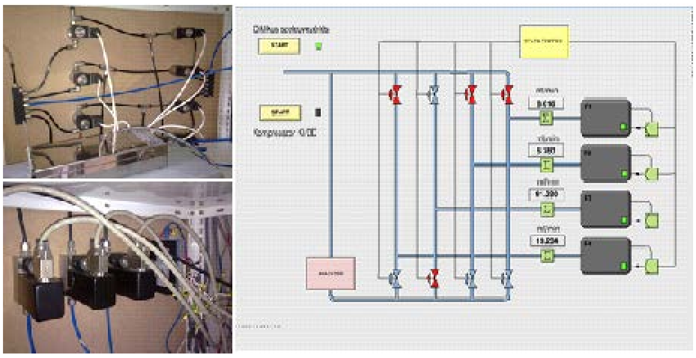


Figure 2: Digital implementation and mass flow controlling system of the anaerobic fermentation process

As a part of this was the evaluation of CView SCADA (Supervisory Control and Data Acquisition) software and determination of the development trends (Tamás et al. 2012).
Pre-treatment of the chicken feather was occurred with *Bacillus licheniformis KK1* strain. The strain was isolated and identified by Kovács et al. 2002, Perei at al. 2004. Keratin degradation rate (%) was calculated from protein content of raw chicken feather and protein concentration of liquid culture filtrate (Mézes et al. 2014). The inoculum (Liquid digestate) was obtained from a large Hungarian Agricultural Biogas Plant. Batch-tests were carried out at mesophilic conditions (38°C) for 30 days. Mesophilic liquid digestate (2.2 kg), corn silage (0.2 kg), cattle slurry (2.6 kg) and pre-treated feather (0, 5, 7.5 and 10%) was added to the batch digesters *(Figure 3).* All experimental setups were performed in triplicates.


Figure 3: Batch anaerobic digestion with pre-treated chicken feather

Quantity parameters of raw materials were measured before setting up experiments, and after that was calculated a weighted average of dry matter- (DM %) and organic matter content (oDM %) by each the experiments *(Table 1).*

Digester number	**1**	**2**	**3**	**4**
Pre-hydrolysed feather%	0	5	7.5	10
DM%	3.9±0.5	3.7±0.6	3.7±0.4	3.6±0.4
oDM% in DM%	3.1±0.4	2.8±0.3	2.7±0.5	2.5±0.2

Table 1: Average DM and oDM (%) by different experiments

The highest DM and oDM (%) was calculated by the control experiment without hydrolysed feather. The DM and oDM (%) were determined according to the standard methods. Carbon and nitrogen content of raw materials were analysed by Elementar VARIO EL universal analyser. Hanna Instrument HI2550 multifunctional device was used to pH, ORP (mV), temperature (°C), EC (mS/cm), TDS (g/l), NaCl (%) measuring (measuring limit: 0-14±0.01 pH; ±999.9±0.2 mV; ±2000 ±1 mV; -20-+120°C±0.4; 0-500±1 mS/cm; 0-400±1 g/l; 0-400±1 %). Phosphate buffer (7.0) was obtained for pH setting from VWR International (USA).
Variance analysis with Tukey's test and independent sample t-test was applied to examine differences between the control and different treatments by 5% significant level.

RESULTS

Analysis of biogas raw material and process of anaerobic digestion

The biogas raw materials were analysed before anaerobic degradation process *(Table 2).* Under these parameters were calculated the optimal DM, oDM (%) content and C/N ratio of the digesters. C- and N-content of biodegraded feather was also calculated (Mézes et al. 2014).

Raw materials	**Corn silage**	**Cattle slurry**	**Liquid digestate**	**Pre-treated feather**
DM%	26.00±2.73	3.60±0.52	2.80±0.91	19.94±1.36
oDM %	93.00±3.35	82.70±3.89	72.40±4.02	96.40±2.31
C:N ratio	27.60	13.00	18.00	1.47
C-content	45.80±0.87	40.40±2.40	47.30±2.07	15.09
N-content	1.70±0.29	3.10±1.21	2.60±0.25	10.26

Table 2: Quality parameters of biogas raw materials

During the anaerobic digestion process was controlled the pH, conductivity (mS/cm), Total dissolved solid (g/l) and NaCl% content of the liquid digestate samples and after the digestion process liquid and solid digestate have been separated. The results of the analysis are shown the *Table 3, 4 and 5.*

pH	**Liquid digestate**	**Liquid digestate**	**Liquid digestate**	**Solid digestate**	**Solid digestate (pH_{KCl})**
Sampling time	**1. day**	**10. day**	**30. day**	**30. day**	**30. day**
1. Digester	8.20	8.00	9.85	8.80	8.60
2. Digester	6.80	6.70	8.15	8.71	8.46
3. Digester	6.20	6.40	7.79	8.82	8.34
4. Digester	6.20	6.30	8.55	8.67	8.10

Table 3: The pH values of liquid and solid digestate

After applying more than 7.5% of pre-treated feather ratio the pH was decreased intensively in the 1th day. Between the pH values was not detectable a significant difference by the liquid and solid digestate after 30 day *(Table 3).*

Conductivity (mS/cm)	**Liquid digestate**	**Liquid digestate**	**Solid digestate**
Sampling time	**1. day**	**30. day**	**30. day**
1. Digester	18.77	13.51	5.32
2. Digester	20.26	27.88	5.82
3. Digester	15.86	23.64	6.78
4. Digester	16.89	15.55	5.47

Table 4: Conductivity (mS/cm) values of liquid and solid digestate

After the anaerobic digestion process could be detected three times higher conductivity values in liquid digestate than solid digestate *(Table 4).* In case of the liquid digestate the total dissolves solid values were also higher than in case of solid digestate.

Biogas production of biodegraded chicken feather

Upon the results of the experiments it can be stated the mixture rate of the raw material that contains both cattle slurry and poultry feather determined the biogas production significantly *(Chart 1).* Under mesophilic conditions the mixture rates of 5% result in a favourable production, the amount of the produced biogas (Nm^3 day-1) exceeded the values of the production at mixture rates of 7.5 and 10% by far (50%). The 5% mixture result the highest methane yield, the maximal value was 0.38±0.18 Nm^3 kg-1 DM, second was the control experiment (0.35±0.21 Nm^3 kg-1 DM) after 30 days, therefore did not show any significant differences between control and 5% experiments. Anaerobic digestion process of 7.5 and 10% mixture was stopped after 22 days despite the initial high biogas yields. Under methane yields two groups could be selected. Control, 5% experiments and 7.5, 10% experiment showed significant differences.

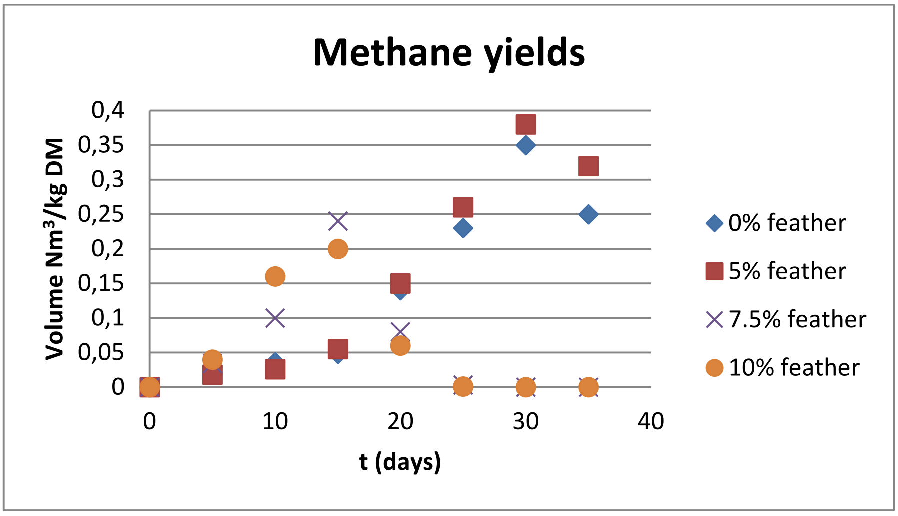


Chart 1: Methane production during co-digestion of different pre-treated feather ratio

Biogas quality analysis

The biogas quality in case of the poultry feather mixture rate of 5 showed better results and differed significantly from the rates of 7.5 and 10%. In case of treatments with a feather mixture rate of 5 methane concentrations around 60% stayed stabile *(Chart 2).*

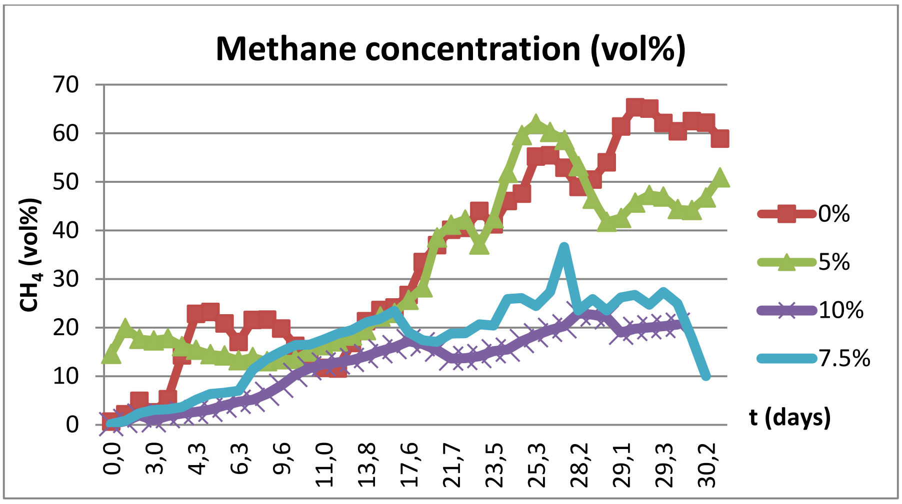


Chart 2: Methane concentration (vol%) production during co-digestion of different pre-treated feather ratio

The amount of H_2S – that has a corrosive effect and causes bad smell – was significantly increased in case of a feather mixture rate of more than 7.5% at the beginning of the fermentation and it affected the methane production negatively. In case of the mixture rates of 7.5 and 10 the hydrogen sulphide concentrations of the produced biogas – in contrast to the higher mixture rates – were more favourable and showed a significant difference in the first phase of the production.

Biogas controlling system

Adaptive fuzzy control of the biogas process was introduced. CH_4 and CO_2 proved to be most effective input indicator components and C/N ratio and NH_4 content can be controlled by fuzzy algorithm. The mean output variables, so the intervention parameters were temperature, mixing intensity and acid dosage *(Figure 4).*

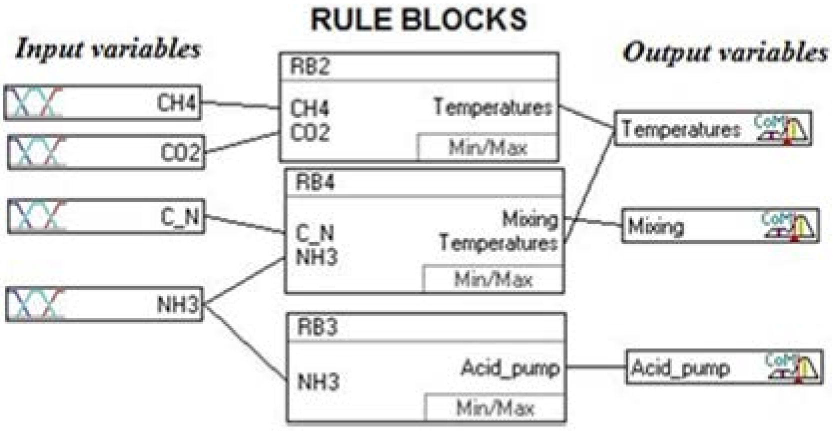
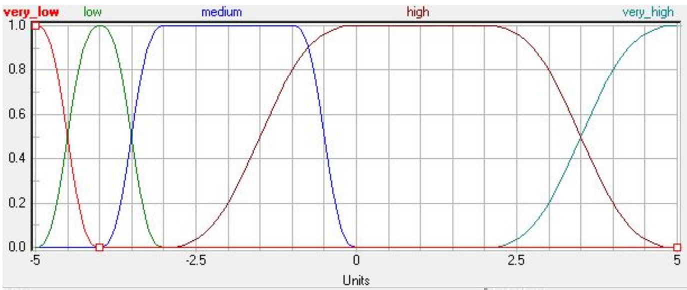


Figure 4: Adaptive fuzzy control of the biogas process

IF/THEN fuzzy convention, which regulates external conditions of biogas production, was evaluated in case of temperature. Effect of different temperature on CH_4 and CO_2 production shows the *Figure 5.*



IF		THEN	
CH4	CO2	DoS	Temperatures
high	very_low	0.90	very_high
very_high	very_low	1.00	very_high
medium	very_low	0.60	high
very_low	very_low	0.20	medium
low	very_low	0.20	high
very_high	low	1.00	very_high
high	low	0.90	high
medium	low	0.60	high
low	low	0.20	medium
very_high	medium	1.00	high
very_low	medium	0.80	low
medium	medium	0.50	medium
high	medium	0.50	high
low	medium	0.30	low
very_high	high	1.00	high
very_low	high	0.90	very_low
low	high	0.90	low
medium	high	0.60	low
high	high	0.50	medium

Figure 5: Effect of temperature on CH_4 and CO_2 production

DISCUSSION

Salminen and Rintala (2002) reported his study, that feather waste has 0.2 methane potential (m^3 kg-1 VSadded) and 0.05 methane potential (m^3 kg-1 wet weight). Comparison our results with his study, the pre-treated feather waste has higher biogas yields. Forgács et al. (2011) reported 0.35 Nm^3 kg-1 VS methane production of feather after biological pre-treatment with *B. licheniformis ATCC 53757* strain, which biogas yields were similar then our results.
The production of the hydrogen sulphide reached its maximal value (170 ppm) already on the 8th day in case of the 10% treatment. Regarding the ammonia content of the biogas it can be stated that the produced amount was significantly high in the first stage, because the most of the easily degradable nitrogen. After that this value decreased as the not so easily degradable forms were degraded. This process was more balanced. In the first stage of the ammonia production a significant difference could be revealed between the following groups: 0, 5 and 7.5% and 10% treatments. In the much more balanced ammonia-producing final stage three groups could be differed: 0% treatment build the first, and 5% was the second.

CONCLUSIONS

Positive effects on biogas production:
In our case 2.5% pre-treated feather ratio result in a favourable biogas production, the highest methane yield was 0.38±0.21 Nm^3/kg DM, second was the control experiment (0.35±0.18 Nm^3/kg DM) after 30 days. Control, 5% experiments and 7.5, 10% experiments showed significant differences, while the 7.5 and 10% was in the third group. These treatments showed a significant difference.

Negative effects on biogas production:
The produced biogas (Nm^3 day-1) exceeded the values of the production at mixture rates of 10% by far (50%). Anaerobic digestion process of 7.5 and 10% mixture was stopped after 22 days despite the initial high biogas yields. Due to the amount of produced hydrogen sulphide (ppm) the critical mixing ratio of feather proved to be 7.5% in laboratory environment. The production of the hydrogen sulphide reached its maximal value (170 ppm) already on the 9th day in case of the 10% treatment. Three treatments group could be selected in case of the highest ammonia concentrations (control and 5% and 7.5, 10%) which were detected after 18 days. Above 7.5% inhibitory effect was observed in case of produced ammonia.

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