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THE REASERCH OF DRY CHICKEN MANURE METHANOGENESIS STABILITY

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Abstract. The studies were conducted in batch mode in thirteen repetitions at humidity of 78, 80, 82 and 84 %. The coefficient of variation of methane production varied from 14.84 % to 35.17 % in a mesophilic mode and from 14.4 % to 78.21 % in a thermophilic mode, which means high instability of the process. The moisture content had a much greater effect on the stability of the process in thermophilic conditions than in mesophilic ones.

Key words: methanogenesis, methane fermentation, chicken manure, adaptation, biogas production, dry fermentation.

1. Introduction

According to the European trends of waste management [4], waste must first be recycled, if it is possible, or utilized with energy production. Such approach can be achieved by methane fermentation. In addition, biogas plant waste is a high-quality organo-mineral fertilizer. On the other hand, in the absence of government standards for this type of fertilizer and the seasonal functioning of the agrarian sector, there is a problem of the formation of an excessive amount of wastewater [11, 17]. The regulation of their amount is possible by conducting solid phase fermentation or recycling of the liquid phase. However, providing both these methods for the poultry waste may cause nitrogen accumulation problems.

Previous studies of organic waste dry fermentation prove a number of its advantages. Thus, dry fermentation provides the reduction of the size of biogas plant, the decrease in the operational cost and higher volumetric methane output [7, 16]. Dry fermentation of chicken manure is relevant but poorly investigated. The purpose of this work is to investigate and analyze the possibility of dry methanogenic fermentation of chicken manure.

Methane fermentation (MF) is divided into dry and liquid according to moisture content. This is due to the fact that at a certain moisture content the substrate loses its fluidity. There is no generally accepted distribution limit for dry and liquid fermentation. However, many authors determine this limit equal to 85 % [8, 9, 11].

The results of our previous studies indicated the possibility of chicken manure dry fermentation, but it was characterized by a significantly lower performance than liquid phase fermentation. Some repetitions of dry fermentation were characterized by a significantly higher yield of biogas and methane compared to the mean value, which may indicate the possibility of a methanogenic consortium to adaptation [13, 14, 15].

Other authors who carried out experimental studies of chicken manure dry fermentation received different results of biogas and methane production, which may prove instability of the process (Table 1). However, there was no research devoted to the study of instability of this process.

Table 1

Results of previous studies of dry fermentation

Author	TS content, %	Temperature, °C	Methane yield, ml/g VS
S. Zhadan et al. [13, 14, 15]	16-28	35,50	
M. Šinkora et al. [16]	23	38	247
F. Abouelenien et al. [2]	22.5	37	5
R. Rajagopal et al. [12]	30	20	162
C. Farrow et al. [5, 6]	20	35	140
C. Farrow et al. [5, 6]	20	35	217
F. Abouelenien et al. [3]	20	35	136.9
F. Abouelenien et al. [3]	20	55	129
F. Abouelenien et al. [1]	25	35	8.2
F. Abouelenien et al. [1]	25	45	6.2
F. Abouelenien et al. [1]	25	55, 65	0
G. Markou et al. [10]	15	35	117
G. Markou et al. [10]	20	35	51
C. Farrow et al. [6]	20	35	470*

*Biogas yield

2. Experimental part 20 g of substrate with 10 % of active sludge was placed in the reactor.

The research was carried out in plastic reactors with a total volume of 50 ml in thirteen repetitions. 20 g of substrate with 10 % of active sludge share were placed in the reactor. Moisture content in the substrate was 78 %, 80 %, 82 % and 84 %. For dilution to the required humidity, tap water was used. The reactors were placed in thermostats. The reactors were operating in mesophilic (35 °C) and thermophilic conditions (50 °C). The experiment was conducted in batch mode for 160 days.

The biogas output was measured daily. The methane content was measured when the required for the analysis amount of biogas (20 ml) was accumulated. The concentration of TS, volatile solids (VS), ammonia nitrogen, free ammonia, volatile fatty acids, free volatile fatty acids (VFA) of a substrate of different humidity was determined at the beginning and at the end of each experiment. T-test and Mann-Whitney test were used for the statistical analysis of the results.

3. Results and discussion

The biogas quantity per mass unit was similar at different moisture content in mesophilic conditions. The biogas yield varied from 294 to 331 ml/g TS, and methane – from 181 to 208 ml/g TS. The maximum biogas yield per mass unit was observed at the substrate moisture content of 84 %. The production of methane per mass unit in mesophilic conditions is shown in Fig. 1.

Biogas production in our previous study of dry methanogenic fermentation of chicken manure ranged from 66.2 to 175.0 ml/g TS, and methane – from 11.9 to 72.0 ml/g TS in mesophilic conditions. The maximum yield of biogas and methane per unit mass was at the humidity of 84 %, which is consistent with the results of this study. Thus, production of biogas and methane was characterized by higher rates than in the previous study [15].

Methane production in the previous studies of other authors was in the range from 5.0 to 247.0 ml/g TS. The largest methane yield was observed in the study of M. Sinkora et al. at 38 °C, which is higher than the results of this study [16].

Biogas production in thermophilic conditions varied from 174.6 to 316.0 ml/ g TS, and methane - from 105.3 to 183.2 ml/g TS. The maximum biogas yield per mass unit was at 82 % of the substrate moisture content. Probably, due to the instability of the process in this study, there was a tendency to the increase in biogas production with increasing humidity just in the range of 78–82 % (Fig. 2).

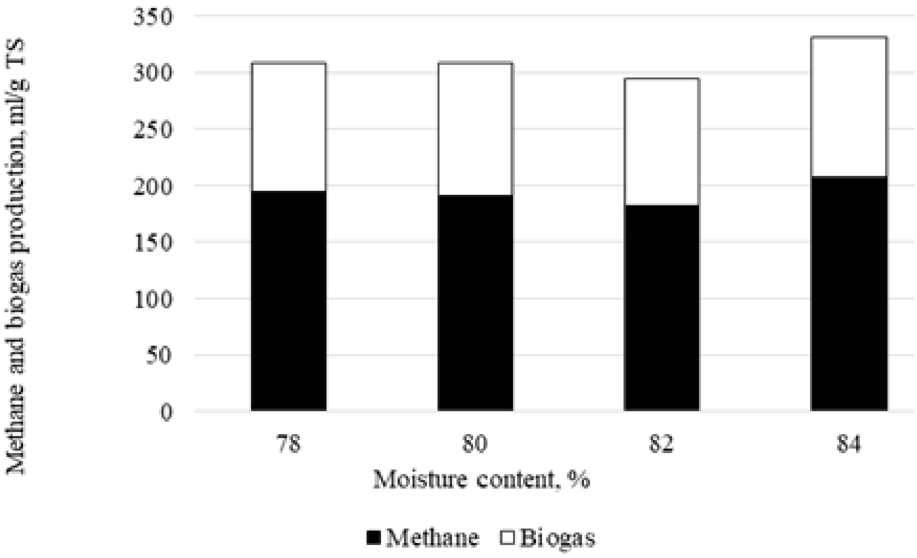

Fig. 1. Production of methane per mass unit in mesophilic conditions

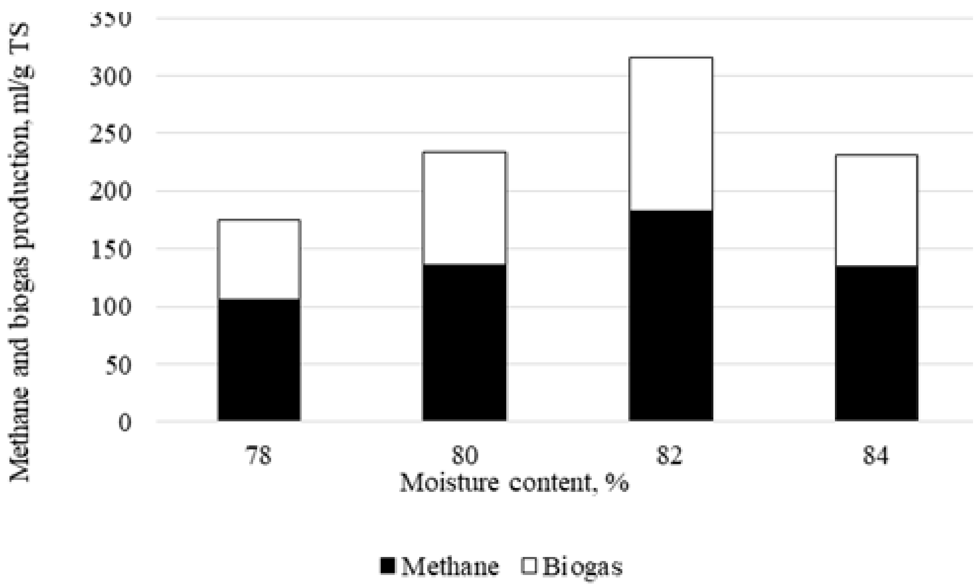

Fig. 2. Production of methane per unit mass in thermophilic conditions

Production of biogas in our previous studies varied from 10.0 to 230.3 ml/g TS, and methane – from 1.0 to 113.0 ml/g TS in thermophilic conditions. The maximum yield of methane and biogas was characteristic of the process with substrate humidity of 84 %.

Production of methane in thermophilic conditions in this study was higher than in our previous study, which is associated with a longer period of the process. The highest methane production rates were obtained by Abouelenien et al. Thus, in their study the production of methane of chicken manure with 20 % of dry matter content at 55 °C was 139.6 ml/g TS [3].

The effectiveness of methanogenesis in this study increased with the increase in moisture content and the effect of moisture on methanogenesis in thermophilic conditions was significantly higher, which was relevant to the results of the previous studies.

The statistical results indicate that a significant difference in the production of biogas and methane between mesophilic and thermophilic conditions was observed at moisture content of 78 % (Mann – Whitney, $P = 0.003$ and Mann – Whitney, $P = <0.001$, respectively), 80 (Mann – Whitney, $P = 0.002$ and t-test, $P = 0.002$, respectively) and 84 % (Mann – Whitney, $P = 0.001$ and Mann – Whitney, $P = <0.001$, respectively). Production of biogas and methane at moisture content of 82 % was not characterized by a significant difference between mesophilic and thermophilic conditions (Mann – Whitney, $P = 1,000$ and Mann – Whitney, $P = 0.259$, respectively).

There was no relationship between methane content in biogas and humidity. The content of methane in the produced gas in mesophilic conditions ranged from 61.7 to 62.9 %, and in the thermophilic – from 57.9 to 60.29 %. The ratio of produced methane to biogas at moisture content of 78–84 % of the substrate in mesophilic and thermophilic conditions is presented in Fig. 3.

The statistical results indicate a significant difference between the share of methane in biogas in mesophilic and thermophilic modes at moisture content of 78 % (Mann – Whitney, P = <0.001), 80 % (t-test, P = <0.001) and 84 % (t-test, P = 0.008). The share of methane at humidity of 82 % was not characterized by a significant difference between mesophilic and thermophilic conditions (t-test, P = 0.077).

The coefficient of variation of methane production was used to assess the stability of the process. The coefficient of variation of methane production varied from 14.84 % to 35.17 % in the mesophilic mode and from 14.4 % to 78.21 % in the thermophilic mode. It is worth mentioning that moisture content had a much greater effect on the stability of the process in thermophilic conditions than in mesophilic conditions. The coefficient of variation of methane production in mesophilic and thermophilic modes is presented in Fig. 4.

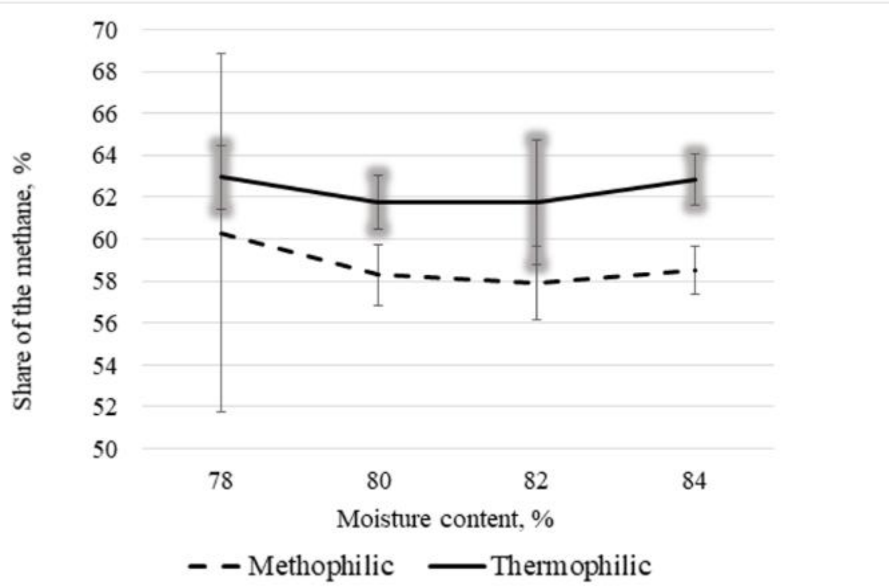

Fig 3. The ratio of the produced methane to biogas at moisture content of the substrate of 78–84 % in mesophilic and thermophilic conditions

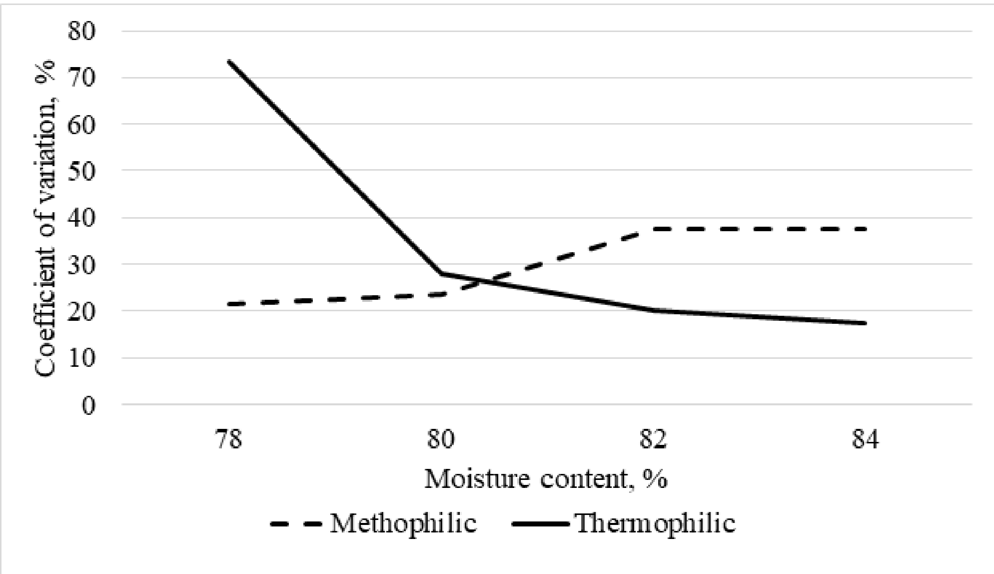

Fig. 4. The coefficient of variation of methane production in mesophilic and thermophilic mode

Thus, the process was unstable both in thermophilic and mesophilic conditions. In addition, the normal distribution of values was not typical for the methane and biogas production, which also indicates low stability of the process. Consequently, dry chicken manure fermentation is not appropriate to reduce water consumption in the utilization of poultry waste.

Changes in the substrate. The content of ammonia nitrogen at the end of fermentation was in the range of 599 mg/l to 4277 mg/l. In general, the content of ammonia nitrogen in thermophilic conditions (from 599 to 3214 mg/l) was lower than in mesophilic (from 2171 to 4277 mg/l).

The content of VFA was in the range from 0.81 to 15.9 g/l in the thermophilic mode and from 0.58 to 2.68 g/l in mesophilic mode. Thus, the content of VFA was higher in thermophilic conditions. The relationship between the content of VFA and the effectiveness of methanogenesis was not detected.

Conclusions

1. For the first time dry methanogenic fermentation was studied in detail.

2. The maximum yield of biogas and methane was obtained in the mesophilic mode at moisture content of substrate of 84 % and it was 331 ml/g TS and 208 ml/g TS, respectively, for the full study period.

3. The process is unstable both in thermophilic and mesophilic conditions. The process in the thermophilic mode is more unstable than in the mesophilic one.

4. It is confirmed that the efficiency of the process increased with the increase in the moisture content; the thermophilic mode was characterized by a greater dependence on the substrate humidity.

5. Dry fermentation of chicken manure is not appropriate to reduce water consumption in the utilization of poultry waste.

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