BIOCHAR APPLICATION IN ANAEROBIC DIGESTION OF MAIZE SILAGE AND CATTLE MANURE

K. Bułkowska[1], D. Cornel[2], M.Z. Gusiatin[1]

[1]Department of Environmental Biotechnology, Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, Olsztyn, Sloneczna St. 45G, 10-709, Poland

[2] Department of Environmental Engineering and Management, "Cristofor Simionescu" Faculty of Chemical Engineering and Environmental Protection, "Gheorghe Asachi" Technical University of Iași, Iași, Bd. Mangeron 73, 700050, Romania

INTRODUCTION

As a substrate for biogas production, waste from the agri-food industry, the organic fraction of municipal waste, or municipal sewage sludge can be used. Differences in the composition of the substrates and the technological conditions of the process affect the stability of anaerobic digestion. Problems with process stability can arise due to an accumulation of volatile fatty acids and pH decreases. One solution to these problems is the addition of sorbents to the reactor, which can sorb excess volatile fatty acids (VFAs), thereby preventing pH decreases and inhibition of microorganism growth. One such sorbent is biochar, a carbon-rich material that can sorb chemicals onto its surface (Pan et al., 2019). Biochar is eco-friendly because it is formed by pyrolysis of plant materials in low-oxygen conditions (Ambaye et al., 2021).

GOAL

The aim of this study was to investigate the use of the biochar as a stabilizer during anaerobic digestion of maize silage and cattle manure.

MATERIALS AND METHODS

Substrate characteristics. Maize silage and cattle manure were collected from Rogoż in Warmia-Mazury voivodeship (Poland). The maize silage had a dry matter concentration of 364.6 g/kg and an organic compound content of 96.3%. For cattle manure, the corresponding values were 190.6 g/kg and 92.8%. The respective contents of protein, crude fat, and crude fiber in maize silage were 7.14%, 1.04%, and 17.02%; and in cattle manure, they were 15.35%, 1.38%, and 23.47%. The percent contents of cellulose, hemicelluloses, and lignin in maize silage were 16.0%, 18.9%, and 2.7%; and in cattle manure, they were 17.7%, 29.6%, and 13.4%, respectively.

Experimental design and set-up for anaerobic digestion. The laboratory experiments were carried out in two series, which both had constant organic loading rates of 1.85 g VS/L·d and hydraulic retention times of 30 days, but different substrates (maize silage or cattle manure). During the experiments, biochar derived from the pyrolysis of plant biomass was used. First, on days 1–104 of the process, biochar was not used; this was considered the experimental control. Then, biochar concentrations of 1g/L (days 105–135), 2g/L (days 136–174), 3g/L (days 175–209), and 4g/L (days 210–240) were tested. Anaerobic digestion was carried out under mesophilic conditions at 39 °C (± 0.5 °C). The series were conducted in fully mixed reactors with a working volume of 6L. The volume of substrate supplied to the reactor during the day was 200 mL, the same as the volume of digestate withdrawn from the reactor. The volume of biogas was measured with a measuring device The produced biogas was collected in Tadler bags (Fig. 1).

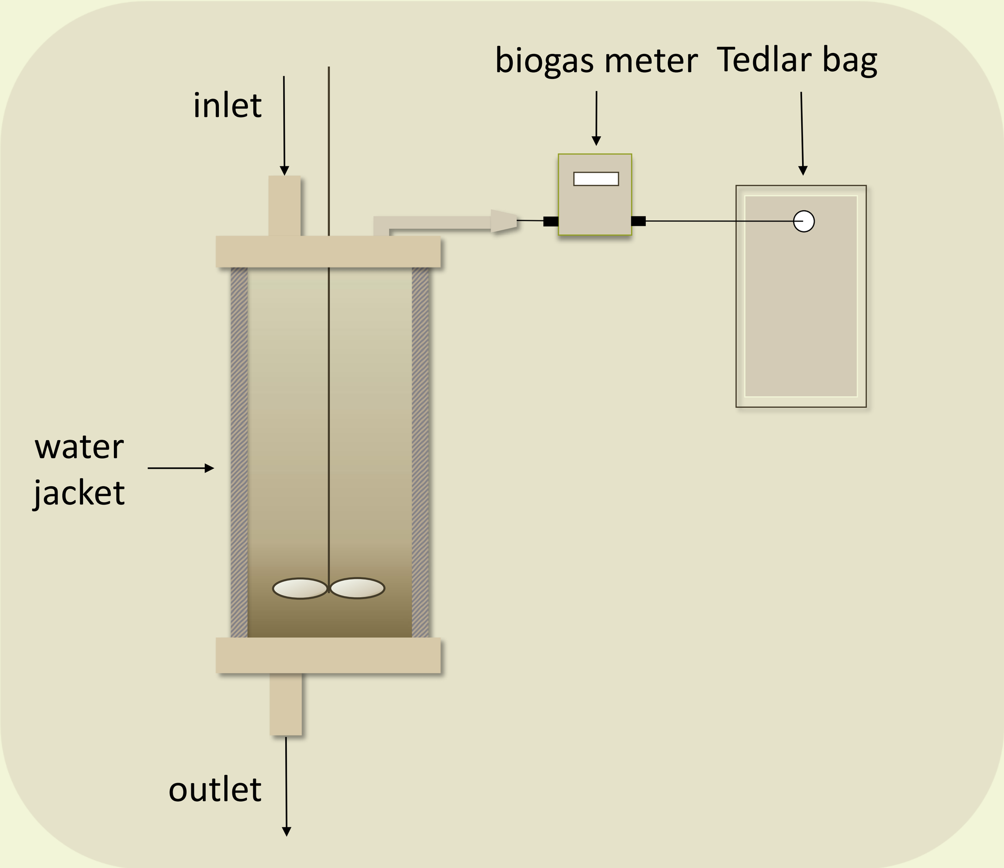

Fig. 1. The scheme of the anaerobic digester.

RESULTS

Effect of biochar concentration on anaerobic digestion of maize silage and cattle manure. The accumulation of volatile fatty acids strongly influences the pH, and in consequence, the biogas and methane production. Biochar addition can prevent rapid inhibition of anaerobic digestion caused by increasing concentrations of VFAs. Figure 2 shows the biogas and methane production during anaerobic digestion of maize silage with various concentrations of biochar, as well as the concentrations of VFAs and the pH. Adding 1 and 2 g/L of biochar did not affect biogas and methane production. However, further increasing the biochar concentration to 3 and 4 g/L caused biogas production to decrease to 4.46 and 0.69 L/d and methane production to drop to 2.18 and 0.10 L CH_4/d, respectively (Fig. 1a). This was due to marked increases in the VFAs concentration at 3 and 4 g/L of biochar along with decreases in the pH. During the anaerobic digestion of maize silage, adding 1-2 g/L of biochar stabilized anaerobic digestion because, as reflected by the pH values of 7.18 to 6.80, VFA concentrations did not increase rapidly.

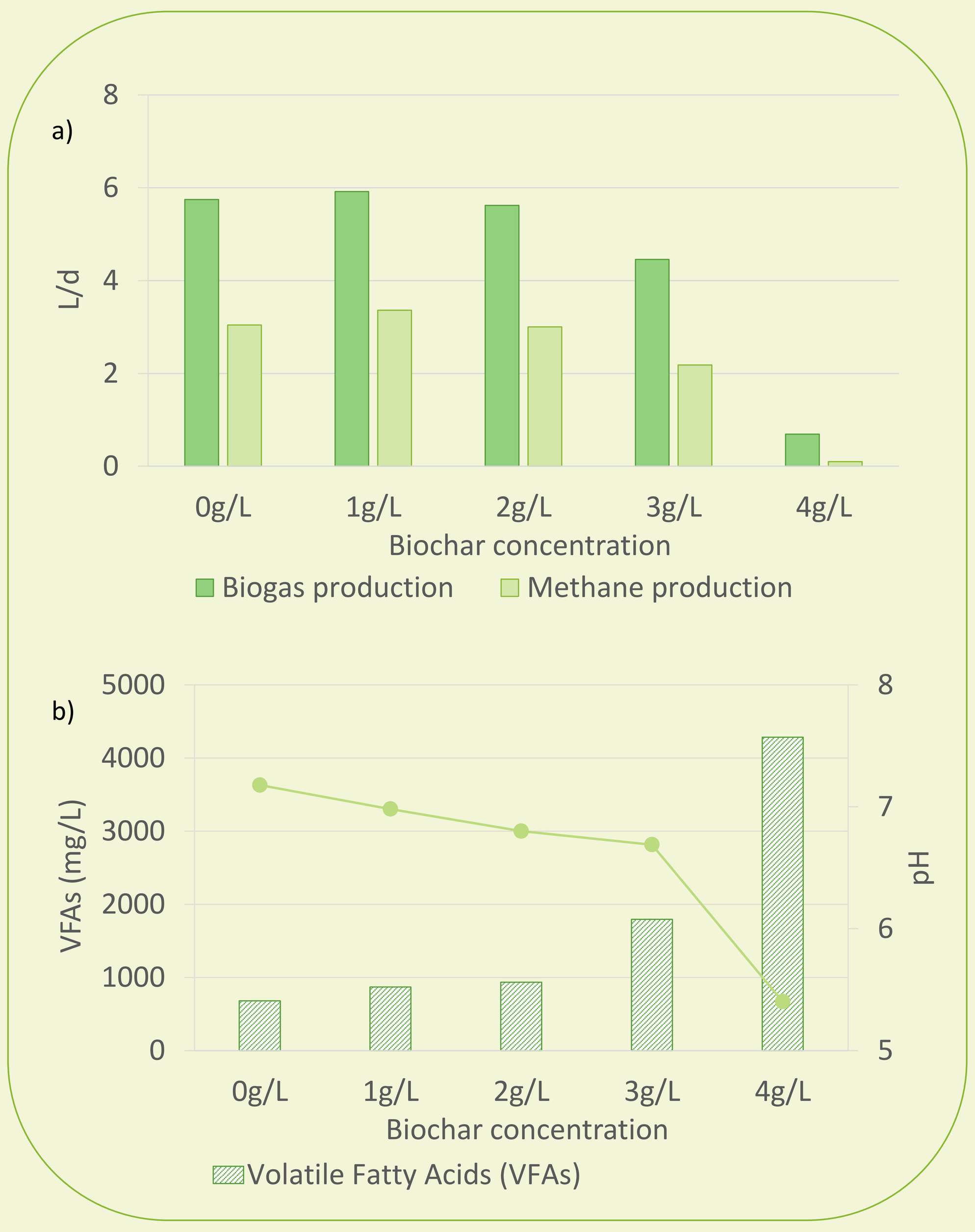

Fig.2. Anaerobic digestion of maize silage with different biochar concentrations: a) biogas and methane production, b) volatile fatty acids concentration and pH.

During anaerobic digestion of cattle manure, biochar addition stabilized the process even when the pH decreased. Figure 3 shows the biogas and methane production during anaerobic digestion of cattle manure and VFAs concentration vs. pH. From the experiments it follows that increasing biochar concentration from 1 to 4 g/L stabilized the anaerobic digestion even when the pH decreasing was observed. The average biogas and methane production independently from biochar concentration was 3.39 L/d and 2.10 L CH_4/d, respectively. During the anaerobic digestion of cattle manure the decrease of pH from 7.26 (0g/L) to 6.91 (2g/L) was observed, but the concentration of VFAs did not exceed 1000 mg/L. Further increase of biochar concentration to 4 g/L even caused the pH increase to 7.26.

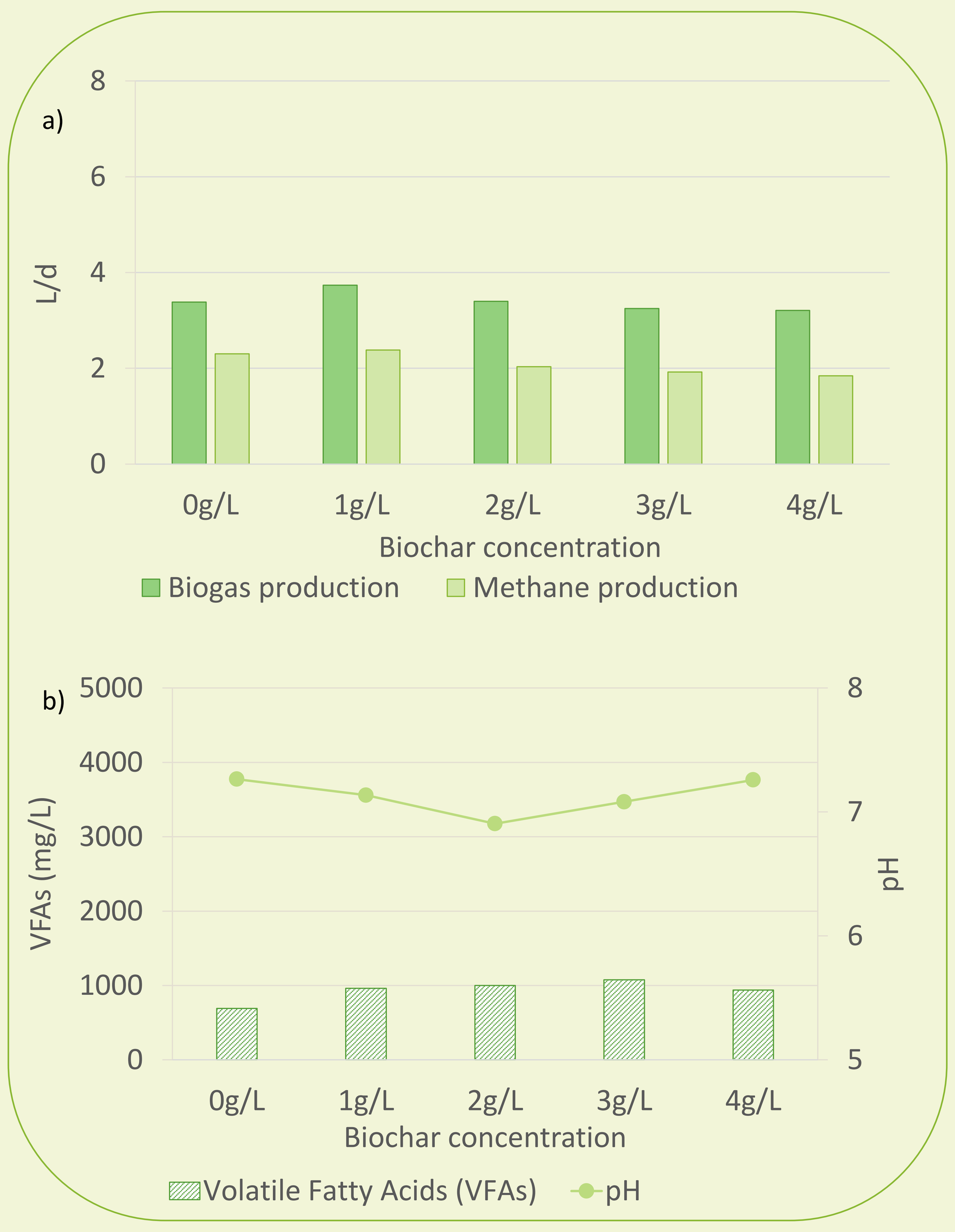

Fig. 3. Anaerobic digestion of cattle manure with different biochar concentrations: a) biogas and methane production, b) volatile fatty acids concentration vs. pH.

CONCLUSIONS

The biochar addition to anaerobic digestion affected the stabilization of the process at specific conditions. When the pH decreased to 6.80, the biochar addition prevented from rapid increase of volatile fatty acids concentration. It means the application of biochar can delay the process failure, which is very important for biogas plant owners, because it gives time to introduce countermeasures that prevent a further decrease of pH and the inhibition the methanogens growth. The decrease of pH below 6.69 caused the rapid increase of VFAs, and the biochar addition did not prevent from the process failure.

REFERENCES

Pan, J., Ma, J., Liu, X., Zhai, L., Ouyang, X., Liu, H. Bioresource technology; 275, 258–265, 2019.

Ambaye, T. G., Rene, E. R., Nizami, A. S., Dupont, C., Vaccari, M., van Hullebusch, E. D. Journal of Environmental Management; 290, 112537, 2021.

FUNDING

Project financially supported by the Minister of Education and Science in the range of the program entitled „Regional Initiative of Excellence" for the years 2019-2022, project No.010/RID/2018/19, amount funding 12.000.000 PLN and National Science Centre, grant Miniature 2, No. 2018/02/X/NZ9/00912.

Keywords:
anaerobic digestion, biochar, digestate, biogas production

KATARZYNA BUŁKOWSKA
Department of Environmental Biotechnology
University of Warmia and Mazury in Olsztyn
katarzyna.bulkowska@uwm.edu.pl