Biochar application in anaerobic digestion of maize silage and cattle manure

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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. Different composition of substrates and technological conditions of the process affect the stability of anaerobic digestion. Due to the problems of maintaining the stability of anaerobic digestion resulting from the cumulation of volatile fatty acids along with decreasing of pH there is a need to find the resolution of this problem. One of the resolutions is the addition of sorbents to the reactor, that can sorb the excess of volatile fatty acids (VFAs), which prevents the pH decreasing and the inhibition of microorganism's growth. Among the sorbents, a carbon-rich material, which has the capacity to sorb chemicals onto its surfaces is biochar (Pan et al., 2019). Moreover, the biochar is formed from the pyrolysis of plant materials, in low-oxygen conditions, which is the eco-friendly feature (Ambaye et al., 2021). The aim of work was to the usage of the biochar as a stabilizer of the anaerobic digestion of maize silage and cattle manure.

Materials and methods

Characteristics of substrates. Maize silage and cattle manure were collected from Rogoż located in Warmia-Mazury voivodeship (Poland). Maize silage was characterized by a dry matter concentration of 364.6 g/kg and the content of organic compounds 96.3%. In the case of cattle manure, the dry matter concentration was 190.6 g/kg, with the organic compounds content being 92.8%. The content of protein, crude fat and crude fiber was 7.14%, 1.04% and 17.02% for maize silage and 15.35%, 1.38%, 23.47% for cattle manure, respectively. Among the lignocellulosic substances, the concentration of cellulose, hemicelluloses and lignin was 16.0%; 18.9% and 2.7% for maize silage and 17.7%, 29.6% and 13.4% for cattle manure, respectively.

Anaerobic digestion experimental design and set-up. The laboratory experiments were carried out in two series, differing in the substrate type (maize silage and cattle manure), at the constant organic loading rate of 1.85 g VS/L·d and a hydraulic retention time of 30 days. During the experiments, biochar derived from the pyrolysis of plant biomass was used. The content of biochar increased from 1 g/L to 4 g/L of the working volume of the reactor throughout the anaerobic digestion. At the beginning from 1 to 104 day of the experiment, the process was conducted without biochar and treated as a control. The experiment was conducted at the biochar concentration of 1g/L between 105 and 135 days of the experiment, then from day 136 to 174 - 2g/L, from day 175 to day 209 - 3g/L and from day 210 to 240 - 4g/L.

Anaerobic digestion was carried out under mesophilic conditions at 39 °C (± 0.5 °C). The series were conducted in fully mixed reactors with an working volume of 6L. The volume of substrate supplied to the reactor during the day was 200 mL and corresponded to the volume of digestate withdrawn from the reactor. The chambers were made of stainless steel and equipped with a stirrer with adjustable speed of rotation and a heating mantle. Appropriately located valves at the top and bottom of the reactor made it possible to supply and receive biogas and digestate from the chamber. The reactors were operated in a *quasi*-continuous system and were fed once a day, after the digestate had been collected. Inoculum from the anaerobic digestion chambers of sewage sludge from the municipal sewage treatment plant in Olsztyn (Poland) was used as inoculation. The produced biogas was collected in Tadler bags. The volume of biogas was measured with a measuring device. The composition of biogas in relation to the maximum content of methane and carbon dioxide as well as the minimum oxygen was determined using an automatic analyzer.

Results

Anaerobic digestion of maize silage and cattle manure with increasing concentration of biochar. The accumulation of volatile fatty acids is one of the most problems affect the pH and in consequences the biogas and methane production. The biochar addition to the anaerobic digestion can prevent from the rapid inhibition caused by increasing concentration of VFAs. Figure 1 shows the biogas and methane production during anaerobic digestion of maize silage with the increasing concentration of biochar and VFAs concentration vs. pH. From the experiments it follows that the increasing concentration of biochar from 1 to 2 g/L did not affect the biogas and methane production. The decreasing of biogas production to 4.46 and 0.69 L/d was noted for 3 and 4 g/L of biochar concentration added as well as for methane production to 2.18 and 0.10 L CH_4/d, respectively (Fig. 1a). It was

caused by rapidly increasing volatile fatty acid concentration at 3 and 4 g/L of biochar addition along with decreasing of pH. During the anaerobic digestion of maize silage, the biochar addition in the range of 1-2 g/L stabilized of anaerobic digestion, because according to decreasing of pH from 7.18 to 6.80, the rapid increase of VFAs was not observed.

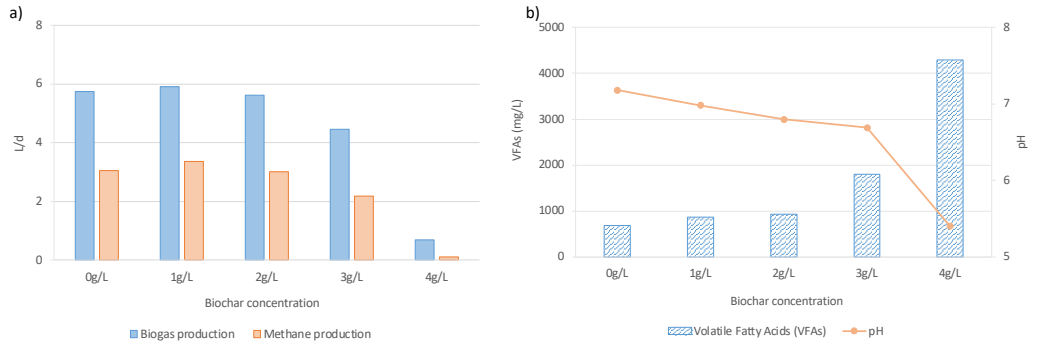

Fig. 1. Characteristic of anaerobic digestion of maize silage: a) biogas and methane production, b) volatile fatty acids concentration vs. pH.

In the case of anaerobic digestion of cattle manure the addition of biochar stabilized the process even with the decreasing of pH. Figure 2 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.

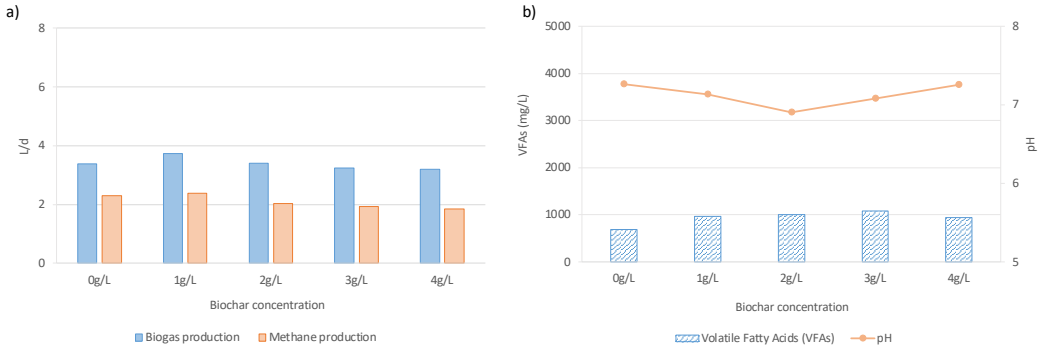

Fig. 2. Characteristic of anaerobic digestion of cattle manure: a) biogas and methane production, b) volatile fatty acids concentration vs. pH.

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.

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