EFFECT OF MICROWAVE AND OZONE PRE-TREATMENT ON BIOGAS PRODUCT OF SEWAGE SLUDGE

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ABSTRACT

Biogas production from food wastes is of growing importance as concerns its environmental benefits, and renewable energy is produced. The production of canned maize is accompanied by the formation of large volumes of waste water, with high contents of starch, and high chemical and biological oxygen demands. Anaerobic digestion is a sludge treatment process that is used in many wastewater treatment plants.

In our work, the effects of acidic, microwave and ozone pretreatment on the biogas production and biodegradability of canned maize production sludge were examined and the energy balances of the processes were determined when different sludge pretreatments were used. It was found that ozone treatment decreased the chemical oxygen demand, while the biological oxygen demand and the biodegradability increased. The combination of microwave and ozone treatment increased the biodegradability relative to ozone treatment alone. The investigation of biogas production showed that all types of pretreatment enhanced methane production: 30-min ozone treatment and 5-min 250-W microwave treatment resulted in a positive energy balance.

INTRODUCTIONMost branches of the food industry, for instance the dairy industry, the meat industry and the cannery industry, have a considerable wastewater output. The problem of pollution is not caused only by the total amount of wastewater production, but also by the high content of organic matter. The production of canned maize produces a high volume of wastewater too, with high chemical (COD) and biological oxygen demands (BOD). After mechanical wastewater treatment, the COD of the sludge may be more than 100 kg m^{-3}, because of the high content of corn starch.

The aim of our present work was to examine the effects of acidic, microwave and ozone pre-treatment on the biogas production and biodegradability of canned maize production sludge. Because of the high energy demands of the processes, their energy balances were also examined.

MATERIALS AND METHODS

The non-pretreated maize canning sludge originated from the DEKO Food Cannery, Debrecen, Hungary. The chemical oxygen demand (COD) was measured before and after the treatments, by the dichromate standard method, in COD tests with an ET 108 digester Lovibond PC CheckIt photometer. The biochemical oxygen demand measurements were carried out in a respirometric BOD meter (BOI Oxidirect, Lovibond, Germany), at 20 °C.

The ozone treatment was performed in continuously mixed solutions diluted to 6% dry matter content. Ozone was generated from oxygen (Linde 3.0) with a flow-type ozone generator (Ozomatic Modular 4, Wedeco Ltd., Germany) operating via a silent electric discharge, and the ozone-containing gas (flow rate 1.0 dm^3 min^{-1}) was bubbled through 180 cm^3 of solution in a batch reactor through a ceramic diffuser. The ozone concentration in the feed gas was measured at 254 nm with a UV spectrophotometer (WPA Lightwave S2000).

The microwave treatment was performed in Labotron 500 professional microwave equipment, at 250 or 500 W microwave power. For the measurements, 200 g of sludge sample was diluted with 200 ml of distilled water in a PTFE vessel, and then irradiated for 5 or 10 min. For acidic and microwave pre-treatment, the pH was adjusted to pH 2 with 1 M HCl.

Biogas production tests were performed in batch mode under mesophilic conditions, at 30 °C for 30 days, in an anaerobic digester with a pressure-measuring head (Oxitop Control AN12 measurement system). The composition of the biogas produced was measured by a gas chromatographic and mass spectrometric method (Agilent 6890N-5976 GC-MS).

RESULTS AND DISCUSSION

In the first series of measurements the COD and BOD were measured (Fig. 1a, 1b).

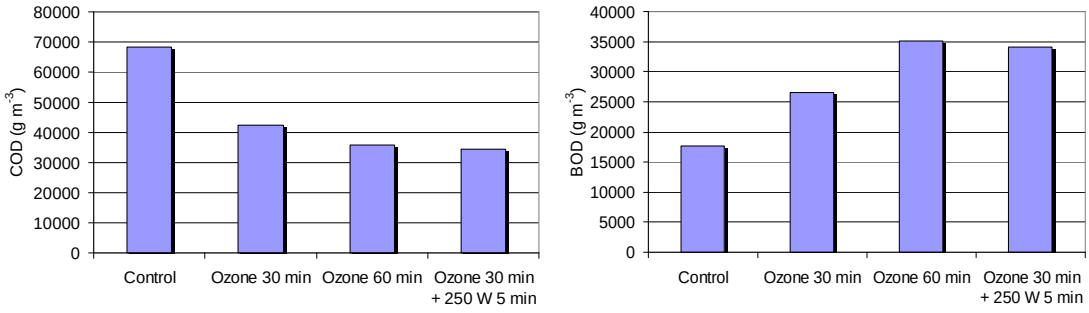

Figure 1. Changes in COD (a) and BOD (b) of diluted sludge solutions due to various treatments

It was found that the ozone treatment and the combined ozone/microwave treatment decreased COD, while BOD increased. After the 30-min ozone pre-treatment, the microwave irradiation caused approximately the same COD decrease as that resulting from the 60-min ozone treatment. At the same time combined treatment was less time-consuming.

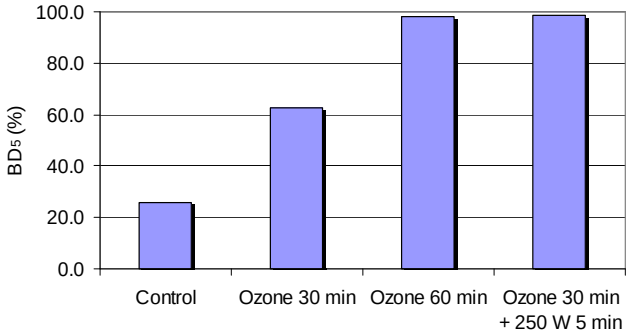

Figure 2. Changes in biodegradability due to ozone treatment and ozone/microwave treatment

The 30-min ozone pretreatment enhanced the biodegradability about to 3-fold, and the 60-min treatment increased it to around 90%. The combination of ozone/microwave treatment increased the biodegradability to close to 100% (Fig. 2).

In the next series of experiments, the biogas production was measured. Gas chromatographic and mass spectrometric measurements showed that after fermentation for 30 days the fermenter contains gaseous CO_2 and CH_4.

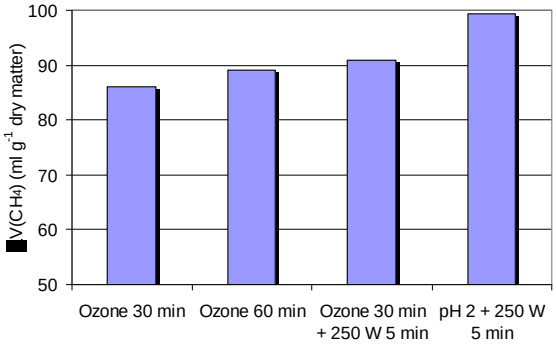

Figure 3. The difference in methane production between the pretreated and control samples

There was no significant difference between the biogas production of the 60-min ozone and the combined ozone/microwave pretreatments. The microwave treatment at pH 2 resulted in a higher methane production.

The initial specific biogas production rate ($dm^3\ kg^{-1}\ day^{-1}$) was calculated as the slope of the straight line fitting the amounts of biogas produced during the initial 10 days of the test [6] (Table 1).

Table 1. Parameters of biodegradability after different pretreatments

Pretreatment	**Treatment time [min]**	**BD_5% (BOD_5/COD)×100**	**Initial biogas production rate [$cm^3\ g^{-1}day^{-1}$]**
Untreated	-	26	1.037
Ozone	30	63	3.77
Ozone	60	94	7.40
Ozone/microwave	30+5	96	9.52
Micerowave (pH=2)	5	95	25.75

The results demonstrate that all of the treatments enhanced the initial specific biogas production rate. When combined ozone/microwave treatment was applied, the increase was 10-fold; however, the acidic microwave treatment enhanced the initial biogas product rate about 25-fold.

As concerns the calculated the energy balance of the treatments, the results showed, that the 30-min ozone treatment and the 5-min microwave treatment at pH 2 were associated with an energy increase, while the 60-min ozone treatment and the combined ozone/microwave treatment needed more energy than that obtained from methane production. (Fig. 5).

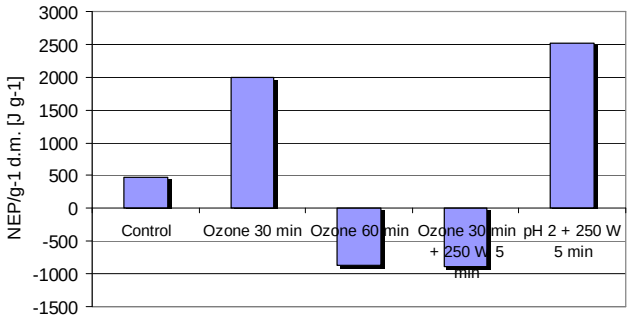

Figure 5. Energy balance of the treatments

CONCLUSION

The results show that microwave treatment alone has no effect on the biogas production of a maize canning sludge, because it does not change the biodegradability of the starch content of the sludge. The microwave treatment of acidic sludge solution resulted in higher biodegradability and enhanced biogas production. Ozone pretreatment and combined ozone/microwave treatment also increased the biodegradability and the biogas and methane production. However, when the processing time is also taken into consideration, the energetic benefits of the pretreatments are not so unambiguous; only the short-time ozone or microwave treatment resulted in net energy production. These experiments indicate that the ozone pretreatment is appropriate for decreasing the organic content of canning sludge, making the organic content of the sludge more accessible for anaerobic degradation, and thereby increasing biogas production.

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REFERENCES

[1] Watenabe H., Kitamure T., Ochi S., Ortega S., Ozaki M., Inactivation of pathogenetic bacteria under mesophilic and thermophilic conditions, *Water Science Technology,* 36 (6-7), 239-246 (1997)

[2] Gavala H. N., Yenal U., Skiadas I. V., Westerman P., Ahring B. K., Mesophilic and thermophilic anaerobic digestion of primary and secondary sludge. Effect of pre-treatment at elevated temperature, *Water Research,* 37 (19), 4561-4572 (2003)

[3] Kim, J., Park, C., Kim, T.H., Lee, M., Kim, S., Kim S.W., Lee, J.: Effects of various pretreatments for enhanced anaerobic digestion with waste activated sludge, *J. Biosci. Bioeng.* 95 (3), 271–275 (2003)

[4] Hyung H., Lee S., Yoon J., Effect of preozonation of flux and water quality in ozonation and ultrafiltration hybrid system for water treatment, *Ozone Science&Engineering,* 22 (6), 637-652. (2000)

[5] Neyens E., Baeyens J., A review of thermal sludge pre-treatment processes to improve dewaterability. *Journal of Hazardous Materials,* B98, 51-67. (2003)