Valorization of maize silage and municipal wastewater sludges: Energy production enhanced by ultrasonic and microwave pre-treatments

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The need for alternative sources of renewable energy like "biogas" has increased the significance of bio-waste such as various agricultural and food production residues, sewage sludge, organic part of household and industrial wastes, etc. (Muller, 2000, Ojolo *et al.*, 2007, Sarkar *et al., 2012).*

The aim of this research is to investigate and improve the biogas production potential of the maize silage (MS), as one of the widely available agricultural biomass products, co-digested with the pre-treated wastewater sludge (WAS) through the mesophilic anaerobic digestion. The pre-treatment/disintegration of the wastewater sludge samples was also realized to increase the performance of the anaerobic digestion process and so the biogas production.

In the study, to increase the solubility of organics and speed up the hydrolysis step, mechanical (ultrasonication) and thermal (microwave) disintegration methods were applied to WAS samples. Before the application of these pre-treatment techniques to the samples, several optimization studies for different ultrasound and microwave conditions were found out. The used ultrasonic homogeniser (Bandelin-Sonopuls HD 3400) was operated at the frequency of 20 kHz, 70% amplitude and a supplied power of 200W. The Speedwave MWS-3+ Microwave Digestion System was the instrument used for the thermal disintegration.

In the set of reactors, a digester containing wastewater sludge alone was operated as a control. Two reactors were fed with the mixture of wastewater sludge and maize silage at the ratios of 40-60% and 50-50%, by mass, respectively to investigate the effect of the co-digestion on the efficiency of anaerobic biodegradability and the biogas production. The other reactors were filled at the same mixing ratios but with the wastewater sludge disintegrated by ultrasonication and microwave methods.

Six identical reactors with a working volume of 1600 mL were used as the anaerobic digesters. The content of the reactors is given at Table 1.

Table 1. The content of the reactors.

Reactors	Content
R1	Inoculum + WAS
R2	Inoculum + WAS (50%) + MS (50%)
R3	Inoculum + WAS (40%) + MS (60%)
R4	Inoculum + ultrasonically disintegrated WAS for 15 min (50%) + MS (50%)
R5	Inoculum + ultrasonically disintegrated WAS for 30 min (50%) + MS (50%)
R6	Inoculum + disintegrated WAS with microwave (50%) + MS (50%)

The applied pre-treatment methods to WAS samples resulted to an increase in chemical oxygen demand in the sludge supernatant as well as TS and VS levels reduction of sludge solids. The application of the disintegration techniques to WAS also caused to a reduction in particle size distribution as presented at Table 2.

Table 2. Changes in the particle size of the wastewater sludge at different disintegration conditions.

	Surface weighted mean D[3.2]	Volume weighted mean D[4.3]	d (0.1)	d (0.5)	d (0.9)
Raw WAS	41.262	96.354	22.642	66.908	160.610
WAS after 15 min ultrasound disintegration	7.776	51.235	3.701	24.415	138.392
WAS after 30 min ultrasound disintegration	5.117	43.515	1.935	19.320	92.458

The results of the study showed that the co-digestion of wastewater sludge with the maize silage appeared to be a more effective solution than the single-substrate digestion in terms of biogas production. The applied disintegration techniques within the study effectively reduced the total solid (TS) and volatile solids (VS) contents and improved the anaerobic biodegradation to a great extent especially in terms of cumulative gas production. The lowest VFA values which were detected in the reactors were also another indicator of a successful anaerobic system. The cumulative biogas production of the reactors is presented at Figure 1.

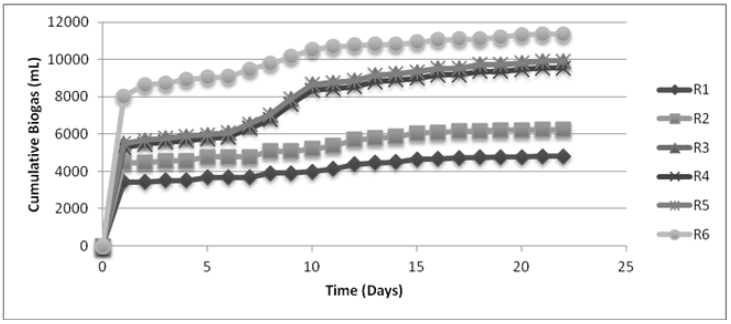

Figure 1. The cumulative biogas production of the reactors

In the batch anaerobic co-digestion of wastewater sludge and maize silage, more efficient anaerobic biodegradation and the enhancement of methane production were obtained especially in the reactors containing ultrasonicated and thermally pre-treated sludge samples. The cumulative biogas production was almost four times higher for the reactor R6 including 30-minute thermally disintegrated sewage sludge than the control reactor R1 containing non-disintegrated sewage sludge. These higher biogas productions in reactors R5 and R6 can be explained with the synergistic effect of the co-digestion and sludge disintegration. The results also showed that the increase in applied sonication time leaded to an increase in the cumulative biogas production.

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