COMPARISON OF MECHANICAL PRETREATMENT METHOD OF ORGANIC WASTE IN WASTEWATER PLANT

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SUMMARY. Organic waste generated at the wastewater treatment plant is a potential source of biogas production. From the point of view of higher gas discharge, it is advisable to pre-treat the individual materials before fermentation. The paper compares the effect of mechanical pretreatment of the substances formed on the site based on anaerobic fermentation efficiency. Based on the results, the communication provides a recommendation for optimum adjustment of the technology and process conditions.

1. INTRODUCTION

Steps of sewage purification - as a main objective -produce primer and secondary surplus sludge, rich in organic matter, is as raw material for the production of biogas at wastewater treatment plants. The pretreatment of the substrate aims to increase the digestion efficiency. Among the methods already proven in this research, experimental or long-used procedures are used in practice. [1] [2] The water purification and the production of green energy from by-product requires the optimum formation of the interconnected technology order. The aim of the research is to examine the effect of a mechanical pretreatment device on the anaerobic digestion of mixed (primary and secondary) sludge and fermentation from the digestion tower. The procedure is compared by the quantity and quality of biogas production.

2. MATERIALS AND PROCEDURES

The pre-treatment procedures integrated into the process of sewage treatment can be integrated into a variety of stages of the cleaning process. An example of this is shown in Figure 1, where star elements marked with serial numbers refer to the possible applications of the equipment.

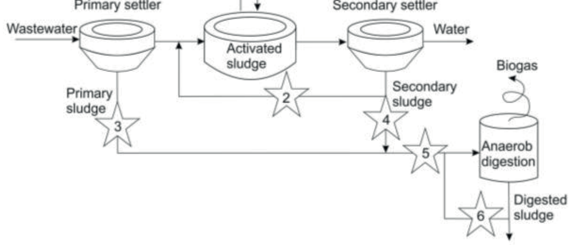

Figure 1Position of sewage treatment technologies in sewage purification [3] 1. simultaneous treatment of active sludge, 2. simultaneous treatment in the active sludge recycle, 3. primary sludge treatment prior to anaerobic digestion, 4. pre-treatment of secondary sludge prior to anaerobic digestion, 5. pretreatment of mixed sludge before anaerobic digestion, 6. pretreatment in the circulation of the organic fertilizer from digestion

The raw sludge to be extracted from the pre-settlers of the sewage plant and the surplus sludge of the biological stages are fed to the sludge treatment works. Aerobic and anaerobic degradation of the organic material in the sewage plant takes place in several stages. All of these are performed by different bacterial groups by biological means. The sludge from the sewage plant fermentor (sludge towers) is pre-condensed, as the reactor volume is constant. More dense sludge feed means greater amount of biomass, which results in the generation of more gas. During the compression process, the starting point is set at approx. 0.5% dry matter content of active sludge, thickened to 5-7% for digestion feed.

For the experiments I used the mixed sludge entering the digestion tower and the digested sludge coming directly out of it, being completely equivalent with the sludge of the digesters. In my experiments the pretreatment technology was inserted n the place of the pre-treatment equipment marked 5 and 6 in Figure 1 i. During my measurements, I determined the characteristics required for the experiment in the examined materials. The pH, dry matter content (TS) and its organic solids content (oTS) were determined on the basis of standard. [4]

1.Typical values ofraw materials

	Mixed sludge	digested sludge
dry material content	5,83%	3,67–3,71%
organic dry material content	79,29%	58,26–64,02%
pH	5,85	7,1–7,6

The fermentation experiment was based on the documentation of the fermentation procedure of VDI 4630 Organic Substances [5]. In my experiments I used an seed sludge for anaerobic fermentation of both substrates. I blended the mixed sludge with the and the pretreated digested sludge was seeded with its own untreated sample.

During the experiments, anaerobic fermentation was performed as liquid process in VDI 4630.

The efficiency of the process can be measured by the qualitative and quantitative increase of the biogas yield of pretreated raw materials. During fermentation at 37 C^{o}, the amount of biogas produced was determined on a daily basis by the volume displacement principle. At the same time, the quality of gas, i.e. methane content, was measured by chromatography.

The preprocessing technology equipment tested in the experiment carries the SHARK fantasy name. The machine is a cutting mill type wet grinder. Mechanical pretreatment was performed with this device (Figure 2). In the wet grinder surface roughening and dectruction are carried out on the principle of liquid crushing and collision. In the equipment, an internal rotating disk accelerates the applied substrate with up to about 8% dry matter to about 170 m / s, generating significant shear forces at the boundaries of the layer, thereby scattering a substantial portion of the particles. The machine is suitable for multiple recirculation of aqueous medium under industrial conditions.

The engine speed can be controlled by a frequency inverter. The machine operating at 200-3500 rpm can also be used for multiple recirculation of aqueous suspensions.

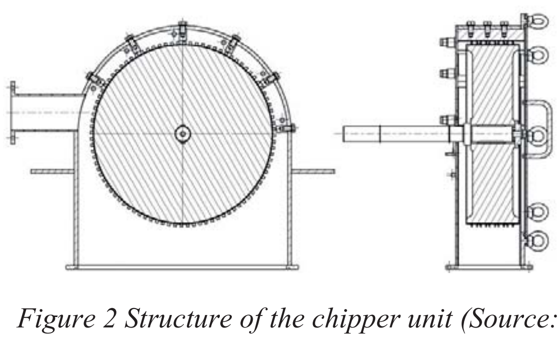

Figure 2 Structure of the chipper unit (Source: own picture)

It operation is based on simple physical principles. Due to velocity difference between the teeth placed on the drum wall and the fluid, significant shear stresses occur which result in destruction at the boundaries of the solid material in the flowing fluid. In addition, the treated material crashes with high velocity into the 6 prism -shaped counterparts bolted to the inner part casing. Then, the treated material falls back at the rotating drum and met the next prism. During continuous progress, the structure of the treated raw material is destroyed and its crystallinity decreases, so that the surface accessible for the bacteria is growing. The aim of the experiment is to examine the effect of the treatment conditions on the raw materials. the variable conditions (parameters) in this case the speed of the equipment and the number of repetition (recirculation). In such case, their small scale systematic alteration would result many experiments

Therefore, the experimental space and the compilation of the experiment were supported by Design of Experiment (DOE) found in the Hungarian and international literature. [6] The planned laboratory anaerobic fermentation test was carried out on the basis of international and national standards and recommendations. I used the variance analysis and statistical program for statistical analysis of the results of the experiment (ANOVA, MINITAB software).

2.table The design of experiment

Shark number	**Sludge type**	**rpm**	**Recirculation**
S1	mixed	2500	3
S2	mixed	2500	9
S3	mixed	1600	3
S4	mixed	1600	9
S5 centrum point	mixed	2050	6
untreated	mixed	0	0
S1	digested	2500	3
S2	digested	2500	9
S3	digested	1600	3
S4	digested	1600	9
S5 centrum point	digested	2050	6
untreated	digested	0	0

In the experiment, the variables with the effect on the examined values (biogas and methane yield) were determined.

Determining Factors and Levels:

speed,

2400 rpm;

1600 rpm

Recirculation,

3times;

9times

These values are based on the experience of my previous experiments. [7]

Factors have been set at two extremes. To check linearity, one centralpoint was set. $2^n = 2^2 = 4$ and 1 centralpoint setting resulted in the compilation of a total 5 complete plans. In each experiment I worked with repeated and parallel samples.

3 RESULTS

3.1 Biogas and methane yields for the investigated raw materials

The mixed sludge experiments lasted an average of 10 days. Summary values of the mixed sludge biogas and methane yields are shown in the diagrams in Figures 3 and 4.

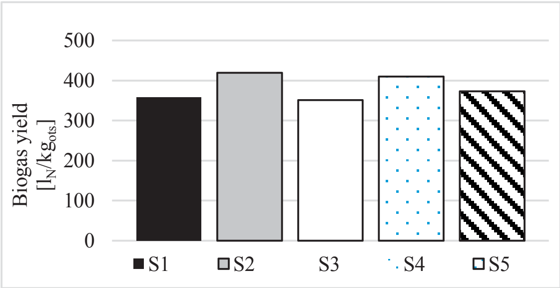

Figure 3 Biogas yield of mixed sludge

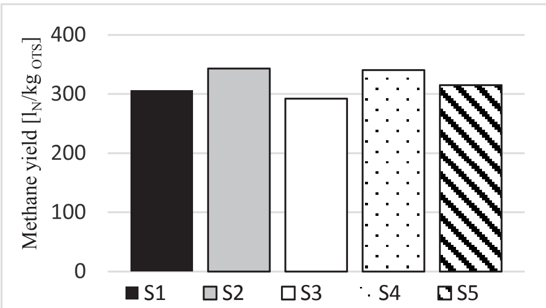

Figure 4 Methane yield of mixed sludge

From Figure 3, it can be seen that the treated samples of the mixed sludge have a biogas yield between 351 l_N/kg_{oTS} (S3) and 421 l_N/kg_{oTS} (S2). The yield of biogas in the untreated sample is 367 l_N/kg_{oTS}. The highest yield of methane is 343 l_{NCH4}/kg_{oTS} (S2) and the lowest is 292 l_{NCH4}/kg_{oTS} (S3) (Figure 4) Methane yield of untreated mixed sludge 297 l_{NCH4}/kg_{oTS}.

The sludge experiments lasted for 9 days on average. Its values are much lower than those of mixed sludge. The quantitative downturn is due to the fact that the the organic solids content of this raw material is far less since it has undergone an anaerobic digestion. When analyzing the treated fermentation fluid, I found that during its post-fermentation the biogas yield was between 148-157.4 l_N/kg_{oTS}. The average biogas yield of untreated fermentation fluid was 127. l_N/kg_{oTS}. The center point S5 gave the lowest gas output.

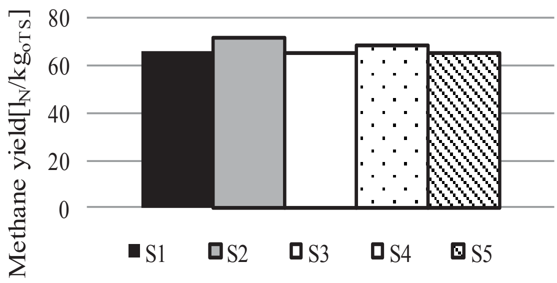

Figure 4 Methane yield of mixed sludge

Methane yields ranged between 37.0-71.6 l_{NCH4}/kg_{oTS} (Figure 5). The average methane yield of the untreated sample was 37 l_{NCH4}/kg_{oTS} at the end of day 9.

3.2 Analysis of variable parameters of pretreatment based on biogas and methane yield

At the end of the anaerobic fermentation I compared the biogas and methane yields to the untreated sample. The values of these differences were evaluated by the ANOVA method. The surplus effect diagram of the mixed sludge biogas yield from the MINTAB program can be seen in the following Pareto diagrams.

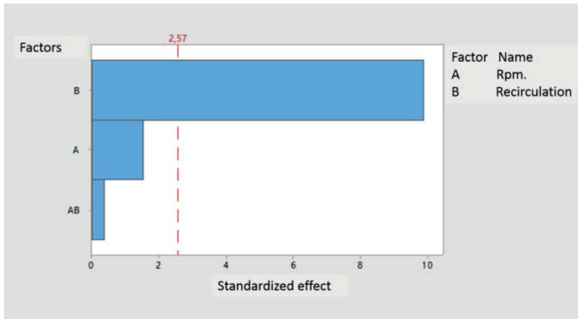

Figure 6. Examined factors of biogas yield of mixed sludge by mechanical shredder treatment

It can be seen that the effect of the speed is negligible in terms of yields. For mixed sludge, only the number of recirculations has a significant effect on fermentation (Figure 6). Similarly, the Pareto diagram of the methane yield surplus also verificated this.

There is no interaction between the recirculation and the speed at either gas or methane yield. Yields are significantly increased by increasing recirculation – the speed had no such effecz.(Figure 7).

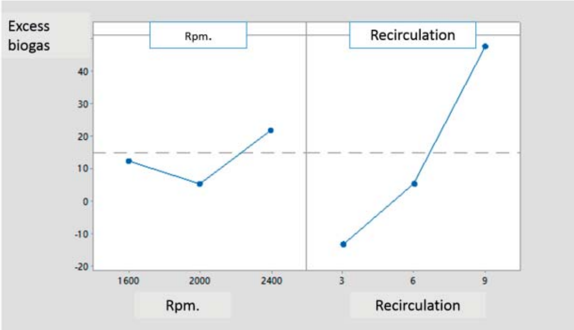

Figure 7 In case of mixed sludge, the effect of speed and recirculation on the excess methane content

During the experiments, high recirculation was the most efficient and the speed was not a factor. It follows that if the pre-treatment energy requirement is taken into account, the optimal adjustment is high recirculation number (9x) and low speed (1600rpm). [8]

As a result of this study, I estimated the regression function of the expected value of the surplus of biogas produced by anaerobic digestion of mixed sludge treated with Shark pre-treatment equipment:

$$\textit{surplus biogas} = -58{,}2 + 0{,}0061n + 8{,}28R + 0{,}00092nR \quad (1)$$

$$\textit{surplus methane} = -69{,}2 + 0{,}0244n + 11{,}72R - 0{,}00230nR \quad (2)$$

where n- speed
R- number of
n·R – joint effect of speed recirculation.[8]

For the digested sludge, Figure 8 shows that in case of biogas yield, the effect of the speed and recirculation, as well as the recirculation, shows a 95% significance level. It can be seen that the larger recirculation results in greater gas output in the space defined by the experimental settings (Figure 9)

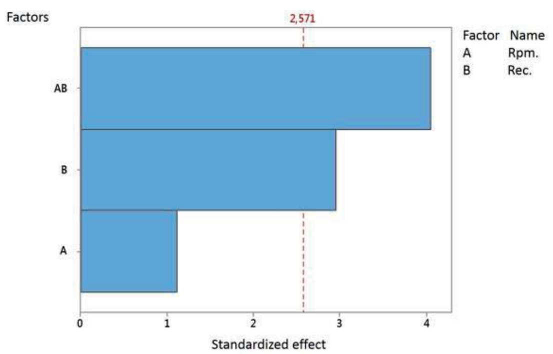

Figure 8: Factors of biogas yield from treatment of digested sludge with mechanical shredde

When examining the interaction of speed and recirculation, it can be stated that the effect by the number of recirculations at the low speed is negligible in the gas yield (Figure 9). At higher revs, however, with high re-circulation settings, the high biogas yield surplus is produced.

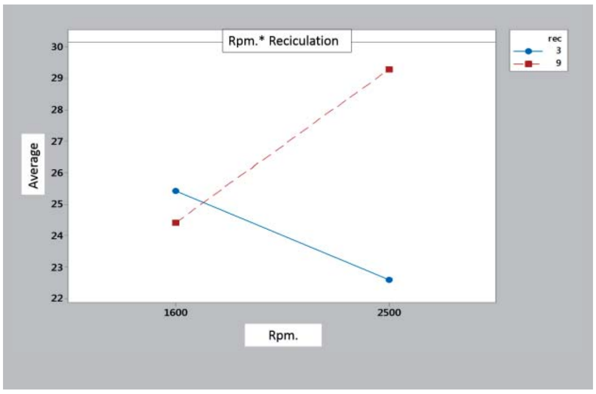

Figure 9 Interaction of the speed and the recirculation in the case of digested sludge

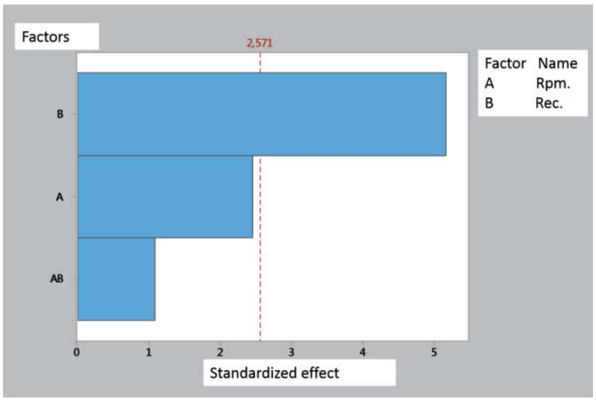

Figure 10 Test Factors for Methane yield of sewage plant Fermentation liquid Treated by Liquid shear and Collision.

The methane yield is inflienced by the recirculation (Figure 10). Increasing the repetition rate increases the methane output as well. The speed approaches the 95% significance limit. [9]

Measured values and statistical analysis can be used to estimate the regression function of the predicted value of the biogas and methane surplus produced by the anaerobic digestion of the fermentation liquid treated with shear and impact principle:

$$\textit{biogas surplus} = 37{,}8 - 0{,}00740n - 2{,}46R + 0{,}001428\, nR \quad (3)$$

$$\textit{methane surplus} = 25{,}26 + 0{,}0027n + 0{,}032R + 0{,}000355nR \quad (4)$$

where n- speed
R- number of

n·R – joint effect of speed-recirculation.[9]

The statistical analysis, based on the above, provides an opportunity to adjust the parameters of mechanical pretreatment of both raw materials tested, which are both appropriate for both the yield values and the energy input of the shredding process.

4. CONCLUSION

In the case of mixing sludge, only the recirculation has a significant effect on the gas yields in the set parameters of the device when operating the liquid shear and impact principle. With respect to measured results, it is certain that biogas and methane yields will increase with higher recirculation. Since speed is not a significant parameter for yield values, therefore, treatment should be performed at low revs with high recirculation, observing energy invested in pre-treatment. [8]

It can also be stated that during the after-fermentation of the sewage sludge pre-treated with the equipment operating on the liquid shear and impact principle the recircilaton affects the biogas and nethebe yield. The recirculation is proportional to the yields, they increase together-The yields also effected by the speed-recirculation interaction. At low speed, the number of recirculation is negligible, with high revs, a high recycle, gives biogas yield surplus

Based on preliminary energy estimates, it is confirmed that the energy demand for the operation of the equipment is high. The energy gain of the methane surplus and the energy used by the equipment can be achieved during the postfermentation of the digested sludge at a low speed with a low recycle number treatment.

The results summarized in the communication provide useful information for biogas plants using pretreatment. Although the surface increase of the raw material has a clear advantage over biogas yield, we should not ignore the energy demand of the process. It's not safe to use the technology with the highest yields. Careful consideration should be given to the factors influencing the achievement of economical results in the production of the energy carrier.

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