SZENT ISTVÁN UNIVERSITY

EFFECT OF ANAEROBIC PRE-TREATMENT ON COMPOSTING OF WASTE WATER SLUDGES

ABSTRACT OF THE PhD THESIS

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1. INTRODUCTION, SCOPE

Anaerobic digestion and composting is among the biological methods of stabilization of waste water sludges (reduction of easily degradable organic content and virulence). Treating the waste water sludges with anaerobic processes has the advantage that there is biogas produced during the decomposition which can be used as source of energy. Thus, it serves the guidelines sustainable development more that composting. The anaerobic treatment, however, is carried out depending on the size of the plant; it is economical only in case of plants above 100,000 PE, because of the heat loss and the limited utilization options.

The BIOCEL dry batch technology is applied for the anaerobic treatment of municipal organic wastes (Ten Brmmeler, 1991, 1992). The process has the advantage of low standard technology. To have the decomposition started and the process kept in balance continuously, seeding material is needed, the ratio of which is a critical point of the treatment. The treatment of dry batch anaerobic treatment is not applied specifically for anaerobic treatment of waste water sludge, and the kinetic parameters of the decomposition process are not defined. It is assumed that also the waste water sludge can be stabilized with anaerobic dry batch treatment. The anaerobic treatment has the disadvantage, though, that the quality of the stabilized end product is less favourable and its utilization is limited without further treatment (Juhász, 2002).

The advantage of treating the waste water sludges by composting is that the decomposition if relatively simple, the quality of the end product is more favourable and it is suitable for direct agricultural utilization. Its disadvantage is that methods applying more state-of-the-art technology and requiring less volume consume energy instead of producing it (Epstein, 1997).

To exploit the advantages of both the anaerobic and aerobic processes, composting following digesting is more and more widely applied in practice in stabilization of municipal waste water sludges (Juhász, 2011, Baki, 2013). It is a contradiction that in the case of both treatment methods, the easily degradable organic material is decomposed. It can be assumed that the degree of digestion has an impact on the composting process and the stability of the end product, and the anaerobic pre-treatment of the waste water sludge affects the energy and mass balance of the composting. I did not find information about any study of a joint optimization of the two treatment methods – neither in any national, nor in any international literature.

Based on the above, the main scope of my research is to study the effect of anaerobic pre-treatment of the municipal waste water sludge on the composting.

In my PhD dissertation, I aimed to clear the following topics:

- towards producing sludges treated with anaerobic method to different degrees, to study and justify the treatability of the waste water sludge under conditions of anaerobic semi-dry batch treatment, and to determine the kinetic parameters of the decomposition,
- to determine the progress and degree of the anaerobic and aerobic organic material degradation by laboratory experiments, and then based on test results, to confirm the effect of the anaerobic pre-treatment on the composting process,
- based on my test results and applying calculations from literature, to define the energy balance of composting, and then, with setting up the mass balance of composting, to evaluate the impact of anaerobic pre-treatment on the composting of waste water sludges.

2. MATERIALS AND METHODS

Based on my scopes, first I worked out the laboratory method of the anaerobic pre-treatment in order to be able to produce sludges treated anaerobically to different degrees. After that, by applying the test results, I investigated the compostability of the sludges digested to various degrees in laboratory conditions.

2.1. Materials

2.1.1. Materials used during the methodological experiment of anaerobic pre-treatment

In both experiments I applied digested sludge generated from anaerobic sludge stabilization as seeding material. In order to study the impacts due to the quality of the substrate, I used mixed sludge in the first experiment, and excess sludge in the second one, as substrate.

The dry and organic content, the value of the chemical oxygen demand of the sludges and the methanogenic activity (hereafter MA) of the seed are shown in Table 1.

Table 1: Material characteristics of the sludges

Materials	TS (%)	VS (%)	COD ($g \cdot kg\ TS^{-1}$)	MA ($g\ CH_4\text{-}COD \cdot g\ VS^{-1} \cdot d^{-1}$)
digested sludge *R0* (methanogenic seed 1.)	16.83	68.02	901	0.0232
mixed sludge *K* (substrate)	23.86	69.91	1124	-
digested sludge *R1* (methanogenic seed 2.)	22.99	41.01	477	0.0284
excess sludge *F1* (substrate)	15.25	83.93	1161	-

2.1.2. Materials applied in the study of anaerobic pre-treatment and composting

For studying the composting, as first step, I produced the sludges digested to different degrees in anaerobic way. As their raw material I used excess sludge (as substrate) and digested sludge (as seed). In the course of composting, the proper structure had to be assured, so for this purpose I mixed in dry straw. The dry and organic content, the chemical oxygen demand and the methanogenic activity of the sludges and the straw are shown in Table 2.

Table 2: Material characteristics of the sludges and the straw

Materials	**TS (%)**	**VS (%)**	**COD ($g \cdot kg\ TS^{-1}$)**	**MA ($g\ CH_4\text{-KOI} \cdot g\ VS^{-1} \cdot d^{-1}$)**
digested sludge *R2* (methanogenic seed)	14.67	64.86	865	0.0229
excess sludge *F2* (substrate)	11.28	80.16	972	-
straw *SZ* (structural amendment)	82.54	94.41	614	-

2.2. Methods of substance-examination

The total solid and volatile solid content of the samples were defined by drying and burning to constant weight, on 105°C and 650°C, respectively. The COD of the sludge was measured by using a standard method (MSZ 21976-10:1982). I measured the methane producing activity with a device working with the principle of pressure measurement, according to the guidance of Biotechnion (1996).

2.3. Setting of the experiment

2.3.1. Setting of the methodological experiment of anaerobic pre-treatment

I performed the examination of the effects of the seeding material on the dry batch anaerobic treatment by a series of reactors of a total capacity of 6 dm^3, which consisted of 4 reactors, each of a capacity of 1.5 dm^3, connected in parallel.

The reactors were connected to a gas collecting bag which collected the produced biogas. I put sludge having the same amount of dry organic material into each reactor, and adjusted the dry content in each reactor to the same value. As experimental variable I tested seven different seed ratios. The substrate (excess sludge) to seeding (digested sludge) rates (K:R0 and F1:R1) based on VS were defined on the values of 1:0.5; 1:0.75; 1:1; 1:1.25; 1:1.5; 1:1.75 and 1:2. I also set up a „blind” reactor to be able to deduct the gas production of the digested sludge. We kept the reactors in a room of constant temperature of 30°C.

2.3.2. Setting the experiment of anaerobic pre-treatment

To enhance the methane production of the anaerobic reactor, to the excess sludge as substrate, I added digested waste water sludge as seed in a ratio of 1 : 1.25 mixing ratio which ratio was determined in the course of methodological experiment. In the case of the above seed ratio, based on my test results, I do not have to reckon with the acidification of the system and the inhibition of the anaerobic decomposition process. I put the mixture of excess sludge : digested sludge into a stainless steel reactor of 70 dm^3 capacity. The design of the reactor, except for the external heating, was the same as that of the reactor used by Brummeler et al. (1991). To promote the decomposition process, I collected the leachate generated in the course of the treatment at the bottom of the reactor, and then I had it recirculated onto the surface of the sludge by a pump. I took samples from the reactor after 0 – 10 – 20 – 30 – 40-day retention times; I used them partly to the composting study, partly to determine the dry content, organic content, COD and total N content.

2.3.3. Setting of the composting experiment

In the aerobic degradation test I optimized the conditions of the decomposition, I added straw to improve the structure of the sludges in a way that I added 1.5 dry content units of straw to one dry content unit of sludge.

2.4. Methods

2.4.1. Measuring method of the methodological experiment of anaerobic pre-treatment

The amount of biogas generated was measured by an „A1” type, Schlumberger wet gas meter. The methane content of the biogas was determined with the help of a biogas-analyzer (Fisher & Rosemont BINOS 104). The methane content of the gas was determined by means of the principle of infrared spectroscopy (IR). The amount of biogas and its content of methane produced by the reactors were measured daily during the first week of the experiment, and in every 2-3 days after the first week.

2.4.2. Measuring method of the experiment of anaerobic pre-treatment

Also in the course of the production of sludges anaerobically pre-treated to different degrees, I measured the quantity and methane content of the produced biogas as reviewed in Article 2.4.1 in order to be able to determine the degree of pre-treatment also as organic matter degradation.

2.4.3. Measuring method of the experiment of composting

I studied the composting with a uniquely developed apparatus. With the apparatus, the actual value of the biological oxygen uptake and carbon dioxide production can be determined, in four simultaneously parallelly running reactors. The samples to be examined were placed one by one in stainless steel reactor with 6 l volume. Support is given to the material placed into the reactor, by perforated plate. The reactors were placed in heat-insulated boxes equipped with thermostats. In the course of the experiment, I set the temperature of the reactors to a minimum of 50°C.

The air leaving the reactor was led through magnetic valves to the gas-analyzer device (Fisher & Rosemont BINOS 104). I measured the oxygen and carbon dioxide content of the leaving gas, and thus, in view of the air flow, I defined the oxygen uptake and carbon dioxide production of the decomposition. The test equipment was controlled through a computer by a process control and data acquisition software (Advantech Genie).

2.5. Methods of calculation and data evaluation

I calculated the value of methane production, the organic material degradation and methanogenic activity and the loss of organic material by means of data from literature and physical correlations (Lettinga and Hulshoff Pol, 1990; Alkoaik et al., 2011). I set up the energy balance of the composting by methods from literature, using my test results (Haug, 1980; Finstein and Hogan, 1992). The composting plant was dimensioned based on Haug's work (1986a,b,c). The statistical data analyses were done by SPSS 14.0 software.

3. RESULTS

3.1. Results of the methodological experiment of anaerobic pre-treatment

I studied the anaerobic decomposition of the excess sludge (F1) and the mixed sludge (K) under semi-dry batch conditions. I stated from the amount of the produced methane and the pH of the sludges that under a substrate : seed ratio of 1:1, independently of the substrate quality, the inhibition of the anaerobic decomposition processes has to be counted with.

Figure 1 shows the organic matter degradation of F1 and K sludges against time. For characterizing the rate of the decomposition process, I defined, as the tangent of the fitted curves, the v_{5d} and v_{25d} values characterizing the initial and the exponentional phase. The reaction kinetic parameters are summarized in Table 3.

Figure 1 shows that the organic content of the excess sludge was 50-65% degraded by the completion of the test, while some 30-40% of the organic content of the mixed sludge was broken down. In the case of the excess sludge, the *k* reaction rate constant I measured was almost double of that of the mixed sludge. The t_0 value describing half-life decreased as the seed ratio increased. In the case of mixed sludge, the t_0 value can be higher by 12-16 days than in the case of excess sludge of the same mixing ratio. When comparing the rate of actual degradation, I observed that the values relating to day 5 and 25 are smaller in the case of mixed sludge than in the case of excess sludge. By increasing the quantity of the seed, the degradation rate became higher regarding both sludges. In the case of mixed sludge, the values of actual degradation rate show continuous growth when increasing the seed ratio. At F1 sludge, when increasing the seed ratio, the value of v_{25d} increases less, thus, the positive impact of increasing the seed ratio has limits.

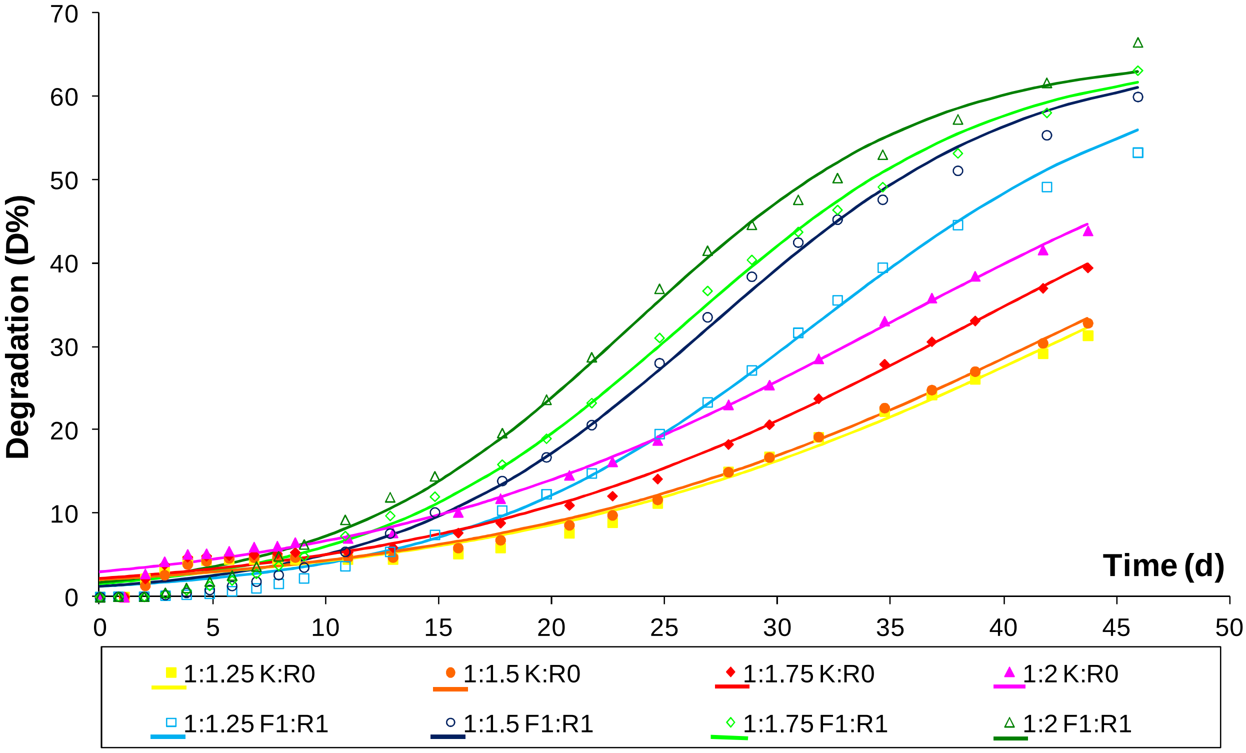

Figure 1: Degradation of organic matter depending on time

Table 3: Reaction kinetic parameters in case of different seed ratios

Reactors	**k** $(1 \cdot d^{-1})$	**t_0** (d)	**v_{5d}** $(D\% \cdot d^{-1})$	**v_{25d}** $(D\% \cdot d^{-1})$	**R^2**
1:1.25 K:R0	0.079	43.9	0.214	0.780	0.985
1:1.5 K:R0	0.080	43.1	0.222	0.811	0.990
1:1.75 K:R0	0.087	38.4	0.273	1.033	0.992
1:2 K:R0	0.088	34.7	0.358	1.204	0.994
1:1.25 F1:R1	0.127	31.6	0.258	1.670	0.995
1:1.5 F1:R1	0.145	27.0	0.350	2.244	0.995
1:1.75 F1:R1	0.145	25.8	0.411	2.303	0.996
1:2 F1:R1	0.153	23.6	0.509	2.447	0.995

The above results show that, during the same period of treatment time, a greater part of the organic content of the excess sludge can be decomposed than that of the mixed sludge. The decomposition rate grows by increasing the seed ratio but the growth is not even. This raises the question as to what extent the already digested material is worth to be recirculated for the purspose of seeding material. Even though the high seed ratio results in a balanced process, it also decreases the effective reactor volume. To answer this question, I calculated the methane production for one reactor volume unit.

I stated that in the case of different sludges, nearly the same methane production for reactor volume unit can be achieved, independently of the seed ratio. At the completion of the 45-day treatment, no significant differences can be detected between the treatments. In case of both mixtures of mixed sludge : digested sludge (K:R0) and excess sludge : digested sludge (F1:R1), I measured the maximal methane production with 1:1.25 substrate : seed ratio. The values of the reaction rate constant reflect that, by increasing the seed ratios, the value of k decreased a little at the excess sludge. The value of t_0 is also greater in the case of mixed sludge than at the excess sludge. Regarding the actual rates of methane production, it can be stated that the actual methane production in day 5 and in day 25 did not raise significantly with increasing the seed ratio.

Based on the average methane production for reactor volume unit, I found that the retention time has to be above 45 days in the case of mixed sludge, while between 35 and 40 days for excess sludge.

3.2. Results of anaerobic pre-treatment

In the course of the trials I prepared waste water sludges degraded to different degrees by anaerobic pre-treatment, in order to study the aerobic degradability. For studying the anaerobic pre-treatment, I applied waste water sludge F2 as substrate and waste water sludge R2 as seed in 1:1.25 mixing ratio. During the test I measured the quantity and methane content of the generated biogas and the pH of the sludge. By day 56 of the trial, 44.5 % of the organic content of the waste water sludge became decomposed. In the first 20 days, 76 % of the organic material got degraded. I sampled the reactor every tenth day, and I used the samples for studying the composting. I did not characterize the sludge samples with the duration of the treatment but with the degree of anaerobic degradation as shown in Table 4.

Table 4: Rate of anaerobic pre-degradation of sludge samples transferred to the aerobic tests

Anaerobic pre-treatment time	Rate of anaerobic pre-degradation
0 d	0%
10 d	25%
20 d	34%
30 d	38%
40 d	42%

3.3. Evaluation of composting experiment

I checked the effect of the anaerobic pre-treatment on the process of composting with the aid of aerobic degradation tests carried out with an apparatus modelling composting. From the value of the summed oxygen uptake I defined the aerobic degradation of the sludges anaerobically treated to different degrees, as shown in Figure 2.

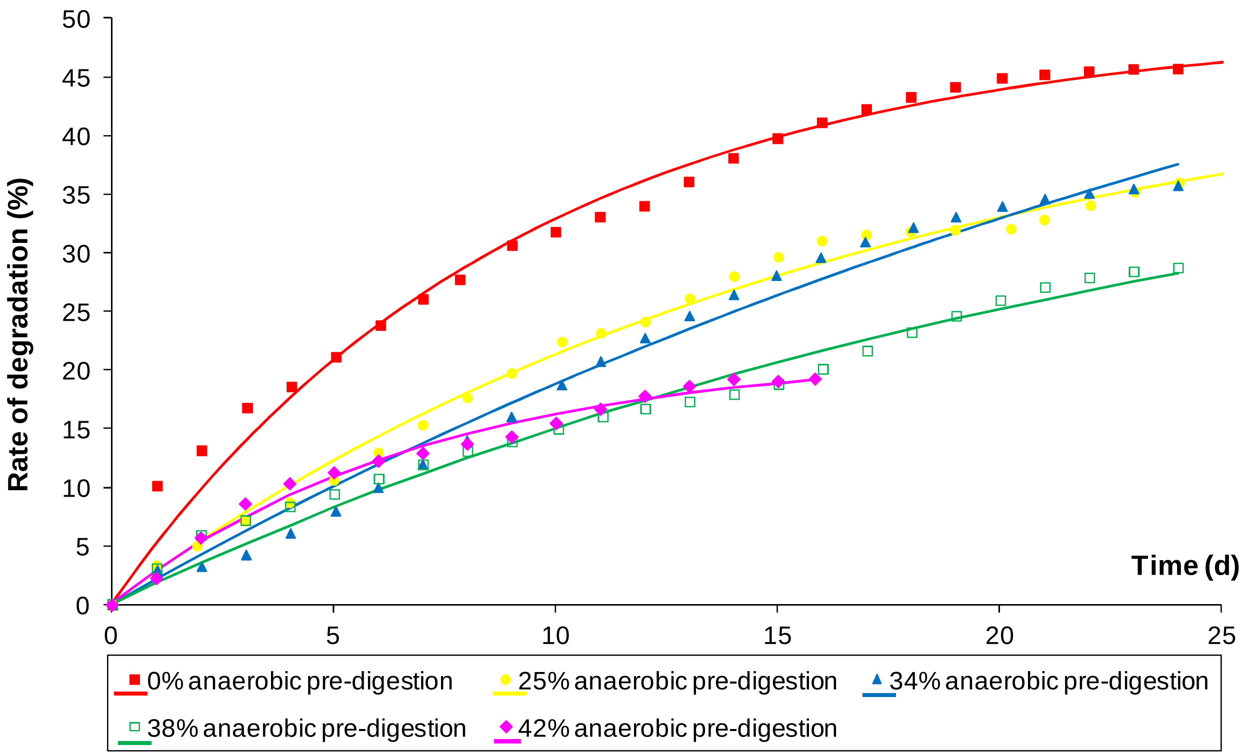

Figure 2: Degree of aerobic degradation of sludges degraded anaerobically to different degrees

Figure 2 shows that the degree of the anaerobic pre-treatment influences the aerobic degradation. The higher the degree of the anaerobic degradation is, the greater is the negative impact in the aerobic degradation. The aerobic degradation of the untreated waste water sludge was 46 % which was close to the aerobic degradability of the waste water sludges (Haug, 1993). It can be said on the whole that, after the anaerobic degradation, the decomposition of the organic material can be further continued under aerobic conditions and an aerobic degradation of significant degree can be achieved. The results of Table 5 show that, above an anaerobic degradation of 34 %, the total of aerobic and anaerobic degradation does not increase significantly. So I defined the optimal degree of the anaerobic pre-treatment as a value of around 34 %.

Table 5: Total degradation of organic matter achievable by anaerobic pre-treatment and composting

Degree of anaerobic pre-treatment	**Aerobic degradability of the anaerobically pre-treated sludge** (T=25 d)	**Total of anaerobic and aerobic degradation**
0%	46%	46%
25%	37%	62%
34%	32%	66%
38%	28%	66%
42%	19% (16 d)	61%

3.4. Comparision of anaerobic and aerobic degradation

Based on my measurement results I stated that, in each case of the same retention time, the degree of aerobic degradation was greater than that of the anaerobic degradation. The detected difference can be also partly explained by the semi-dry anaerobic batch treatment being slower than the liquid continuous-technology treatment.

Table 6 shows the reaction kinetic parameters and the actual rates of degradation (v_{3d}, v_{20d}).

Table 6: Values defined for parameters in first-order reaction kinetics equition acquired by regression analysis

Parameters	Aerobic treatment after			Anaerobic treatment after		
	0%	25%	38%	0%	25%	38%
	anaerobic pre-digestion			anaerobic pre-digestion		
D_{max}	49.41	47.57	45.27	37.92	14.60	8.618
k	0.110	0.060	0.040	0.115	0.094	0.077
v_{3d} (D%/d)	3.905	2.369	1.627	3.093	1.033	0.527
v_{20d} (D%/d)	0.608	0.864	0.812	0.440	0.211	0.143

Table 6 indicates that the degradation rate declines as time progresses and that the rate of aerobic degradation is significantly greater on day 3 and 20 than that of the anaerobic degradation. Comparing the actual rates of degradation, it can be stated that, in the initial period of decomposition (day 3), the greater the degree of the anaerobic pre-treatment is the more the degree of anaerobic degradation achievable per time unit decreases. The rate of aerobic degradation does not change significantly any more on day 20 with the degree of anaerobic pre-treatment, however, the rate of anaerobic degradation further decreases. This is related to the better aerobic degradability of organic materials less degradable (lignin and cellulose) (Angelidaki and Ahring, 1999).

To evaluate the relation between the anaerobic and aerobic degradation, I investigated the values of aerobic degradation in respect to the anaerobic degradation, in the case of the same treatment durations, as shown in Figure 3. I fitted a trend line to the measurement results in order to examine the relation and characteristic of aerobic and anaerobic treatment. It is apparent that, with the increase of the degree of anaerobic treatment, the characteristic of the relation changes during the anaerobic and aerobic decomposition. This is shown also by the trend line fitted to the data points, the tangent of which increases more and more with the degree of pre-treatment, it is 1.19 in the case of untreated sludge, while it is 8.39 in the case of sludge anaerobically pre-treated to 42 %.

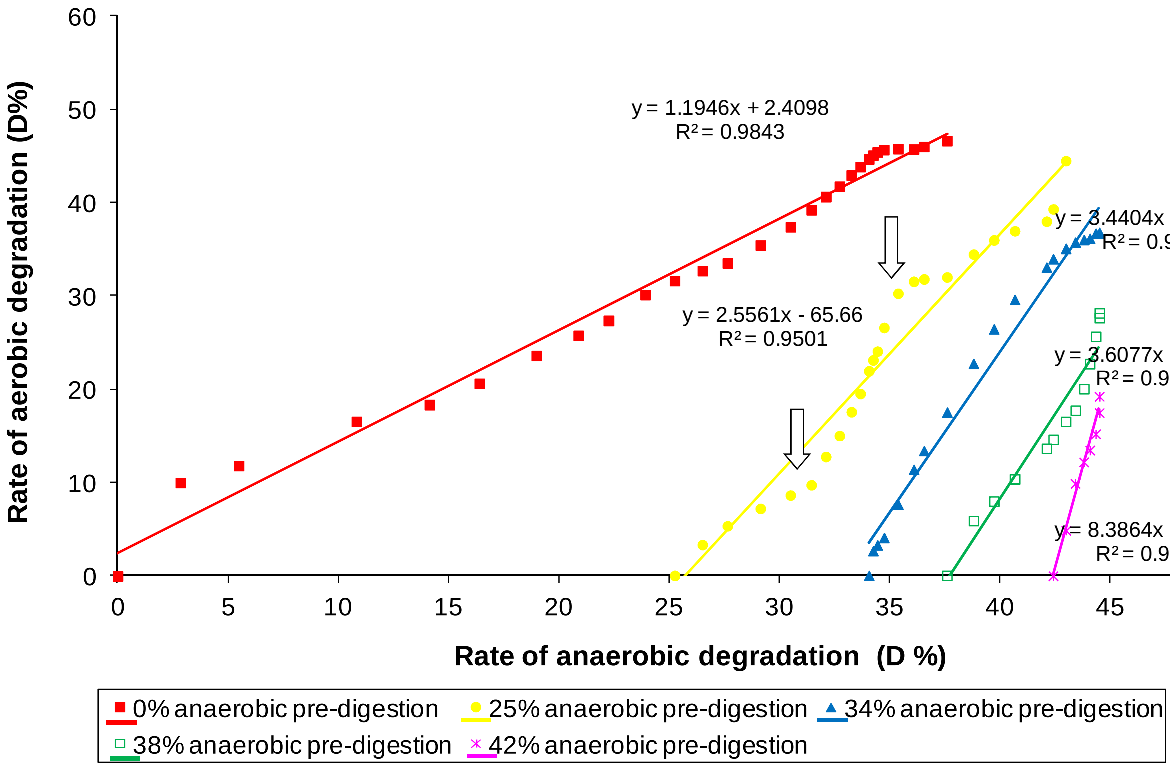

Figure 3: Relation between aerobic and anaerobic degradation of sludge pre-treated anaerobically to different degradation rates

It can be concluded from the above results that the characteristic of the relation changes above a certain degradation, because the aerobic degradation becomes more effective than the anaerobic degradation, therefore beyond a certain degradation level it is preferable to continue the decomposition by aerobic method.

3.5. Energy balance calculations

I calculated the quantity of energy released during composting based on Finstein's and Hogan's work (1992) which is shown in Table 7. The results of the table indicate that the quantity of energy released from the sludges decreases with the increase of the degree of pre-treatment.

Table 7: With 25-day composting, the energy released during composting, projected to one unit sludge dry matter, in the case of sludges pre-treated differently

Degree of anaerobic pre-treatment	Released energy (kJ · kg TS^{-1}) (T=25 d)
D = 0%	7,694
D = 25%	6,211
D = 34%	5,439
D = 38%	4,812

To answer the question whether the organic matter has to be supplemented for energetics purposes or it is sufficient to recirculate the finished compost in order to yield an end product with 60 % dry content, I specified the W_t value and the energy balance of composting.

The value of W_t became W_t=7.5 at 5°C ambient temperature, while W_t=7.8 at 20°C ambient temperature. For the case of sludge samples anaerobically pre-treated to various degrees I defined, at different dry contents, the value of the calculated W which gives the amount of water referred to one quantity unit of biologically degradable organic matter (BOD kg). The relation of the W value defined by me and the dry content is shown by Figure 4.

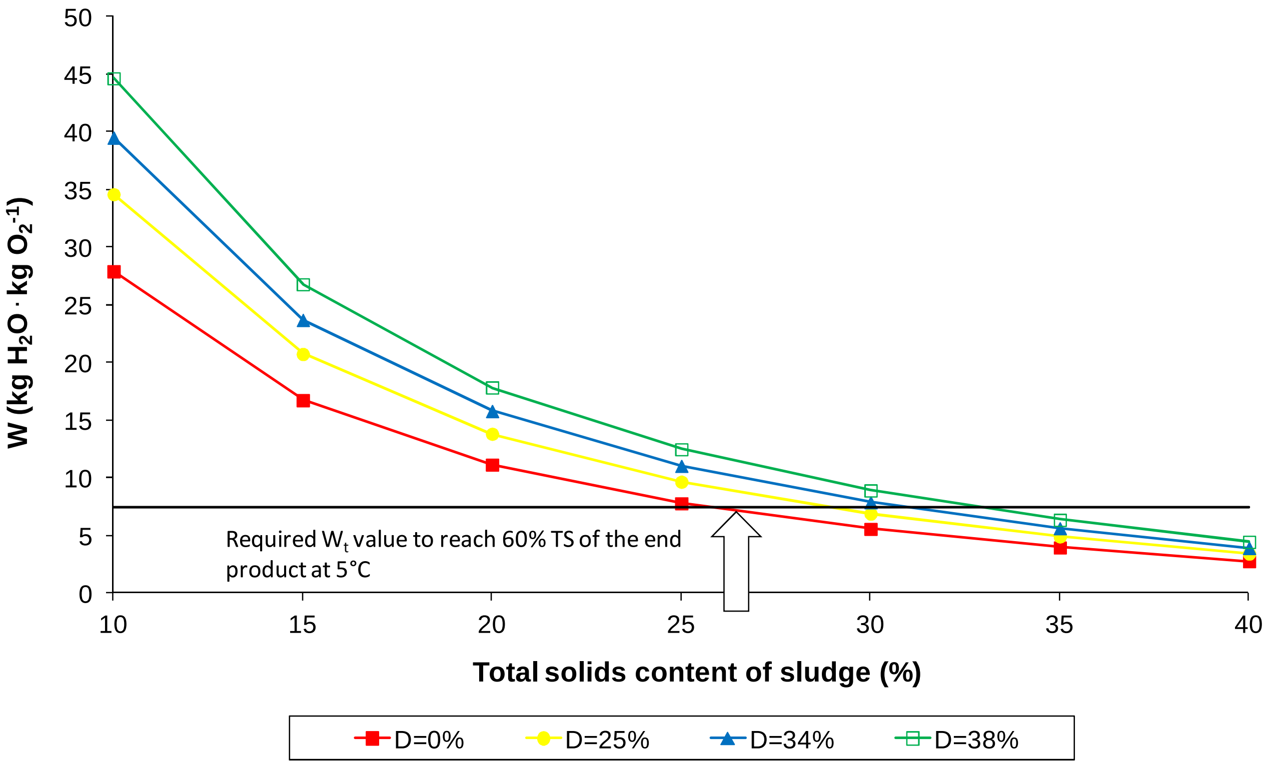

Figure 4: W values of sludges anaerobically pre-treated to various degrees, in respect of the dry content, and the theoretical W_T value

Figure 4 indicates that, up to 25 % dry content, with none of the investigated sludge samples can the end product dry content of 60 % be yielded. In the case of higher anaerobic pre-treatment (34% and

38%), the energy generated from degradable organic material is not sufficient enough with even 30 % dry content to achieve the appropriate dry content. While at the same dry content, for the sludge containing more degradable organic matter and not having been treated with anaerob method, the decomposition of the organic material as well as the drying can already be assured. In case of sludges of 35 % dry contect, the degradation of organic matter and the end product of 60 % dry content can be already achieved at each investigated sample.

I defined the actual energy balance, the difference of the energy production calculatable from the stoichiometric oxygen demand and the energy losses. When calculating the actual heat elimination, it can assumed that the change of heat loss against time is rational with the run of oxygen uptake against time. I did the calculation for sludges having different anaerobic pre-treatment, for 55 °C inner and 5°C and 20°C ambient temperature. At the calculated values, the positive energy balance means that the 55°C temperature can be assured while it cannot be at the negative energy balance. The length of the thermophilic period indicating the duration of the positive energy balances estimatable based on the energy balance calculation is summarized in Table 8. The degree of pre-treatment and the ambient temperature have impact only in the case of around 25 % dry content. At 20 % initial dry content, because of the negative energy balance due to the achievement of the drying target, the thermophilic period cannot be sustained for the investigated priod in any of the cases , while above 30 %, it can be in each case.

Table 8: Estimated duration of the thermopile stage of composting differently pre-treated sludges at 5 and 20°C surrounding temperature

Degree of anaerobic pre-treatment	**Duration of thermophilic stage** (55°C)							
	D=0%		**D=25%**		**D=34%**		**D=38%**	
TS%	**5°C**	**20°C**	**5°C**	**20°C**	**5°C**	**20°C**	**5°C**	**20°C**
20%	0 d	0 d	0 d	0 d	0 d	0 d	0 d	0 d
25%	8 d	17 d	8 d	24 d	10 d	25 d	8 d	23 d
30%	21 d	25 d	25 d	25 d	25 d	25 d	25 d	25 d
35%	25 d	25 d	25 d	25 d	25 d	25 d	25 d	25 d

Having calculated the energy balance at 20°C ambient temperature, also the length of the thermophilic period is observed to increase with the increase of the temperature; this can be explained by less energy loss. The differences cannot be detected above 30 % sludge dry content.

3.6. Sizing of composting

To evaluate the effect of the anaerobic pre-treatment on the demand of energy supplementing additive, I defined the demand of energy supplementing additive of the sludges stabilized to different degrees and the recirculation demand of the finished compost aiming to set the initial 40 % dry content of the mixture (sludges + straw) (structure improvement). The calculations were done on the basis of various sludge dry contents (20 – 25 – 30 – 35 – 40%) and on the dry content of the target product (60%).

Table 9 summarizes the quantity of straw and recirculated compost necessary to a sludge of one dry content unit during composting waste water sludges pre-treated with anaerobic method to different degrees. Table 9 also contains the yields of the waste water sludge and the additive *(Q_{m1})*, the finished compost *(Q_p)*, the recirculated compost *(q)*, as well as the hydraulic retention time *(HRT)* and the treating capacity *(V)*. It shows that the greater the degree of the anaerobic degradation is the more straw needs to be added to supplement the degradable carbon content. The amount of recirculated compost decreases with the increase of the degree of anaerobic pre-treatment and the quantity of necessary straw additive which results in a significant increase of the hydraulic retention time. This, however, affects only the operating system of the composting plant. The volume and area demand of the plant depends on the quantity of the energy supplementing additive which shows increase with the degree of the anaerobic pre-treatment of the waste water sludge.

Table 9: Design parameters of composting differently pre-treated and dewatered sludge, projected to one unit (1 t/d TS) of treated sludge

Degree of anaerobic pre-treatment	**Total solid content of the sludge** (TS%)	**Ratio of energy supplementing straw additive** (TS)	**Ratio of recirculated compost** (TS)	Q_{m1} ($m^3 \cdot d^{-1}$)	q ($m^3 \cdot d^{-1}$)	Q_p ($m^3 \cdot d^{-1}$)	**Hydraulic retention time** (d)	**Volume requirement of composting** V (m^3)
D=0%	20	0.98	1.53	6.6	5.1	4.9	42	345
	25	0.17	1.54	3.9	5.1	2.7	34	199
	30	0.00	1.00	3.3	3.3	2.3	38	168
	35	0.00	0,43	3.3	1.4	2.3	48	168
	40	0.00	0.00	3.3	0.0	2.3	60	168
D=25%	20	1.30	1.05	7.7	3.5	6.0	48	410
	25	0.49	1.06	5.0	3.5	3.8	43	265
	30	0.00	1.00	3.3	3.3	2.5	38	175
	35	0.00	0.43	3.3	1.4	2.5	48	175
	40	0.00	0.00	3.3	0.0	2.5	60	175
D=34%	20	1.47	0.80	8.2	2.7	6.6	51	444
	25	0.66	0.80	5.5	2.7	4.4	47	299
	30	0.13	0.80	3.8	2.7	3.0	43	202
	35	0.00	0.43	3.3	1.4	2.6	48	179
	40	0.00	0.00	3.3	0.0	2.6	60	179
D=38%	20	1.61	0.59	8.7	2.0	7.0	53	472
	25	0.80	0.60	6.0	2.0	4.9	51	327
	30	0.27	0.60	4.2	2.0	3.4	48	230
	35	0.00	0.43	3.3	1.4	2.7	49	181
	40	0.00	0.00	3.3	0.0	2.7	60	181

3.7. New scientific results

I framed the new scientific results achieved in my PhD study in three thesis points as follows:

- I proved with the results of my experiments that the waste water sludge can be treated with anaerobic semi-dry batch treatment. The value of the optimal seed ratio varies depending on the quality of the substrate. It is rendered to be a value of 1:1.25 in case of excess sludge and between 1:1.75 – 1:2 at the mixed sludge, taking into consideration the organic matter degradation and the methane production per unit of reactor volume. The duration of the semi-dry batch treatment of the waste water sludge, depending on the quality of the substrate, is 35-45 days.
- Based on the results of my experiments, I justified that the anaerobic pre-treatment fundamentally determines the aerobic degradability, the value of aerobic degradation decreased from 46 % to 26 % under conditions optimized with anaerobic pre-treatment. Depending on the degree of stabilization gained during the anaerobic pre-treatment, the aerobic degradability increases, compared to the anaerobic one. The relation between further aerobic and anaerobic degradation defined to raw material stabilized to the same degree varies depending on the degradation of the raw material. The ratio of the effecacy of the aerobic/anaerobic treatment increased from the value of 1.19 measured with untreated material to 8.39 as the pre-treatment extended (42.4%).
- By calculating the actual energy balance of the composting, I stated that, under 25% dry content, an end product of 60 % dry content cannot be yielded with any of the sludge samples. I confirmed with calculations that without anaerobic pre-treatment only above 25 % dry content can be a temperature of 55 °C permanently achieved in the compost prism while, in case of a 38% anaerobic pre-treatment, yet 30% dry content is needed. By enhancing the anaerobic pre-treatment, the retention time ensuring the 55 °C decreases. My calculations did not prove a significant effect of the temperature reduction on the energy balance. The degree of anaerobic pre-treatment affects the quantity of the energy supplementing additive. The amount of straw applied to supplement energy can result in 1.6 times' increase with the anaerobic pre-treatment (in case of D=38%, 20% sludge dry content, 60% end-product dry content) compared to the sludge not treated anaerobically.

4. CONCLUSIONS, PROPOSALS

I compared the test results of the semi-dry anaerobic batch treatment with the data of the liquid continuous-technology sludge digester. I stated that, in the case of semi-dry anaerobic batch treatment, during the same period of time, the achievable degree of degradation of organic matter is half of that in case of liquid continuous-technology treatment. Due to the high dry content, however, the semi-dry batch technology can be economical for the treatment of waste water sludges of waste water treatment plants of small and medium capacity.

As long as the waste water sludge digestion is followed by composting, the higher biogas production gained from the sludge can be given up and it is sufficient to have it less digested (according to my calculations: 34 % instead of 60 %). The remaining digesting capacity can be appropiate for treating other organic wastes, thus, the lost gas production can be compensated.

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