SZENT ISTVÁN UNIVERSITY

DOCTORAL SCHOOL OF ENVIRONMENTAL SCIENCES

Monitoring the composting process with the application of new examination method

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Work history and goals set

The reduction of the required organic matter content for landfills, the lack of nutrient content and structural disturbance of soils, the lack of availability of certain nutrients and the spread of biologically treatable wastes provides great opportunity and potential for the establishment, operation of composting plants and utilization of produced composts. The legal framework describes the process of composting (http 1) and the application of compost as fertiliser product (http 2). For more sectors (waste management, food industry, animal husbandry etc.) composting is important and significant, applied as biowaste treatment method, similarly in case of other sectors (horticulture, agriculture, etc.) compost utilization is a demand (Jakusné Sári Sz. – Forró E. 2006).

Parallel to composting and compost production there is a need to determine the changes taking place during the process. Regarding usage the important properties are maturity (Brewer & Sullivan, 2001) and stability (Butler et al., 2001., the Composting Association, 2001, Stentiford, 2002) which largely determine the application conditions whether providing an opportunity or imposing a limit. Many describing - physicial, chemical or biological - methods (Kovács & Füleky, 2016) and parameters are available and in many cases limit values were set such as for C/N ratio (Jiménez & Garcia, 1989; Bernal et al., 1998; or Dewar test (LAGA, 1984).

The organic matter content of composted raw materials (wastes, by-products) decomposes and forms (inter alia) mineralized nutrients and humus-like materials (Bannick & Ziechmann, 1991). The follow up on the processes provides the opportunity of more thorough understanding of composting which is useful in the percpective of waste recovery and soil protection.

The spectral tests were successfully applied for many fields of science, but few methods were applied to study the composting processes provided with scientific substantiation (E_4/E_6) (Sellami et al., (2008), SUVA254., Said-Pullicino et al., (2007). Examination and analyses of different wavelengths and wavelength ranges were recently started (Xi et al., 2012; Song et al., 2015).

During my work I have followed up the nutrient content and other chemical parameters, furthermore the changes of monosaccharide and reducing disaccharide content from hot water (HWP) extraction and I also determined the light absorption characteristics of alkaline and HWP extractions with photometry depending on several factors.

During my work I was looking for answers to the following questions:

- The examination of change (during composting) in sugar content with hot water percolation (HWP) by the determination of easily soluble mono- and oligosaccharide concentration.
- The creation of humus-like materials (during composting) and monitoring on their formation into each other and the examination of light absorption characteristics of compost with spectrophotometry.

- The humus quality parameters, e.g. E_4/E_6 value change observation in compost samples, as a function of starting material and duration of composting as affecting factors to determine compost quality.
- Nutrient element content and certain physical characteristic change monitoring and analyses depending on the raw materials and duration of composting.
- Optical analysis of the effluent cuvettes obtained continuously from compost samples, and mathematical analysis of the spectra. Time dependence analysis of measured spectra with mathematical description of the assumed processes of hot water percolation. Applying the assumed function with nonlinear fitting to the measured data, then analyzing the resulting parameters, which gives an opportunity to interpret the processes taking place during composting.

Methodology

In case of **experiment 1.** I carried out the composting of green waste (from residential collection) by using adiabatic reactor under controlled conditions for 9 weeks. Samples were taken weekly. I determined the monosaccharide and reducing disaccharide content of the hot water extracts by applying the Schoorl method after hydrolysis and without.

For **experiment 2.** I separately composted green garden waste (ZH) from residential collection and fresh cattle manure (MT) from paddock, by the application of operational conditions, covered, closed prism composting. Sampling took place every second day until the 12. day, after on the 28., 42. and 56. days. I have determined the following parameters of the samples: organic matter content with incineration, pH from aqueous and KCl suspension potentiometrically, redox potential from aqueous suspension, ammonuim and nitrate N content from KCl extract with water vapour distillation, readily available phosphorus and potassium content from AL extract with photometry, and flame photometry, electrical conductivity from aqueous suspension with conductimetry. The alkali metals, potentially toxic and toxic heavy metals from nitric acid extract with microwave plasma atomic emission spectrometry. I determined the humic compounds from NaOH extract with Ocean View 1.6.7 spectrophotometer between 400-900 nm. I represented and analyzed the recorded data with Origin 7.5 (Microcal). The E_4/E_6 ratio is given by the ratio of absorbance values read at 465 and 665 nm respectively. According to another method, the function matched to the spectra of the wavelengths between 400 and 900 nm, which I calculated from the function $y = y0 + A1 \cdot e^{-\frac{x}{t1}}$ fitted to function values read at 465 and 665 nm using the formula $e^{\frac{200}{t1}}$ (Sebők et al., 2018). For the hot water leaching I used the device edited on the basis of „Procedure for determining the nutrient content of soils and equipment for performing the procedure" (Patent No. 205,994) by the editors: György Füleky – Imre Czinkota – László Torner – István Horváth. The device carries 100-150 kPa, 103-105 °C water through the sample.

In Experiment 1, I collected two consecutive (100 cm^3) fractions per compost sample. In Experiment 2, the compost solution coming out of the HWP was led into the cuvette of the measuring apparatus in a bubble-free state, where a 12V 5W light source was emitted, which was fed into the Ocean View 1.6.7 spectrophotometer through glass fiber. I used the absorption (light absorption) fuction of the apparatus. The detected data was recorded in the photometer at 400-900 nm (in VIS range), the flow-through for 365 sec, per every 5 sec. I represendted and analyzed the recorded data with Origin 7.5 (Microcal) and Surfer 12 (golden) programmes.

Results

Experiment 1.

Sugar content

After the beginning of microbial degradation the weekly sampling shows a continuous reduction of the actually available (without hydrolysis) HWP soluble monosaccharide and reducing disaccahride content, but significal difference cannot be detected between the certain samplings. The reducing sugar content of the samples after hydrolysis presenting significant differences in many cases, they differ from each other and in most cases from the results of simple HWP extraction. The HWP soluble reducing sugar content and the HWP soluble monosaccharide content values are influenced by the raw material (compost), thus its carbohydrate composition.

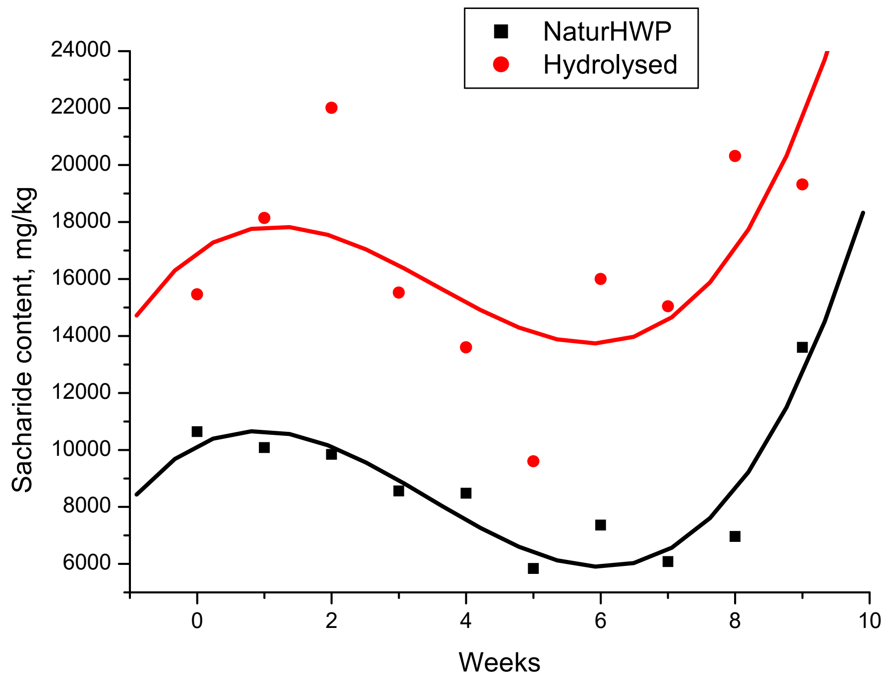


Figure 1: The changes of monosaccharide and reducing disaccharide while the composting progresses in case of hydrolyzed HWP and HWP without hydrolysis

During the composting of examined materials (green waste), the monosaccharide and reducing disaccharide content changes in the same way, but in different order of magnitude after the examination of samples obtained from hot water (HWP) percolation and after hydrolysis. The run of both diagrams can be noted as similar regarding tendency. In both cases the, the process can be described with a polynomial function (Figure 1).

Results

Experiment 2.

Organic matter content

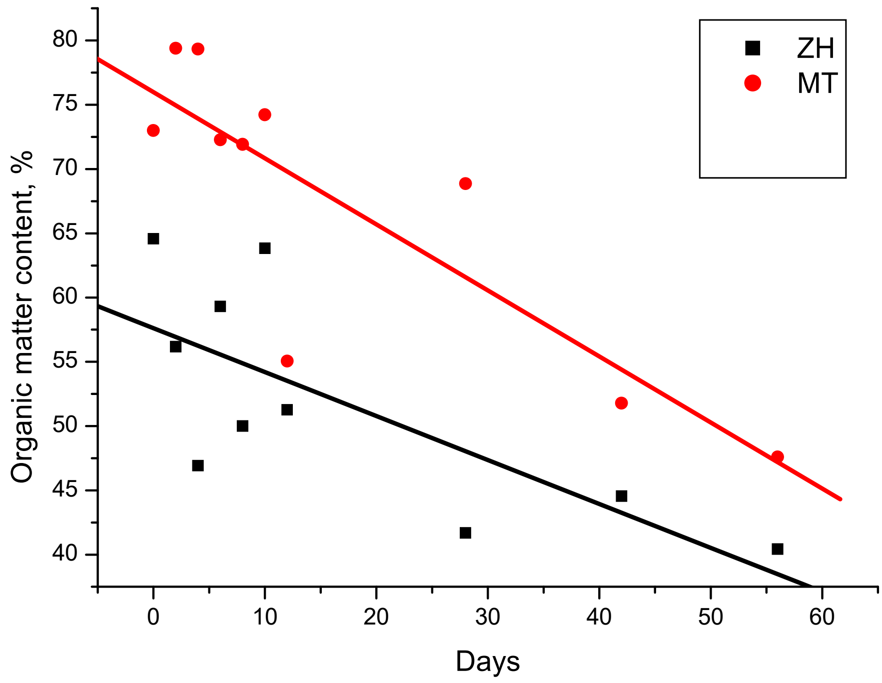


Figure 2: The changes of organic matter content of examined composts as a function of duration

*ZH-green waste, MT-cattle manure

	Intercept	Error	Slope	Error	Correlation
Green waste	57.62	2.72	-0.341	0.11	-0.7365
Cattle manure	75.97	2.85	-0.513	0.115	-0.8429

Table 1: Analysis of functions fitted to the organic matter content of the examined composts

It is clearly visible on the illustrated functions (Figure 2.) and line parameters (Table 1) that in case of the cattle manure the organic matter content shows greater values in the beginning of the composting and the decrease is more intense as for green waste. It decreases with close correlation on the dependence of duration. In case of green waste the initial organic matter content is less and its' reduction is not so intensive. The correlation is less close with duration. The different values were caused by the quality of raw materials because the cattle manure was completely fresh at the start of composting, while the degradation processes were already in place in green waste.

Phosphorus content

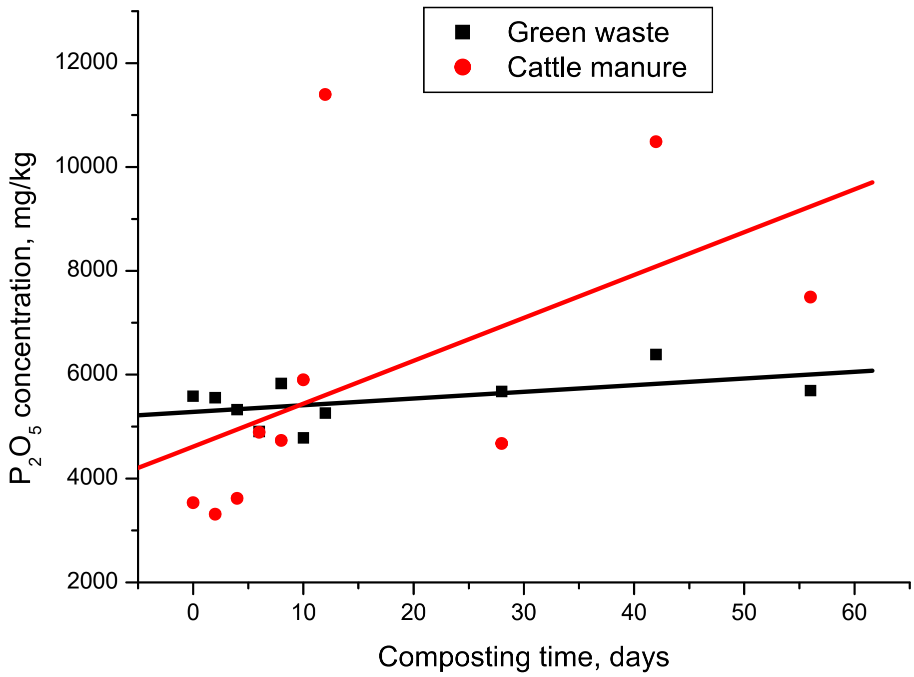


Figure 3: Changes of Al soluble P_2O_5 content of the tested composts as a function of composting duration

	Intercept	Error	Slope	Error	Correlation
Green waste	5284.50208	180.89305	12.85583	7.35556	0.52567
Cattle manure	4616.39167	1114.71858	82.58383	45.32725	0.54153

Table 2: Analyzing the functions of phosphorus content of the examined composts

For green waste it can be singnificantly justified that phosphorus concentration is practically unchanged, the phosphorus content of cattle manure increases (Figure 3), but the standard deviation of the measured data is very high (Table 2), which may depend on the solubility of mineralized organophosphorus compounds.

The contained elemental nutrients in cattle manure, thus phosphorus have also undergone a biological and enzymatic transformation, most of them being bound in nucleic acids, so that phosphorus can be found as easily absorbable in the starting material compared to green waste, so its uptake and dissolution is much more intense, therefore correlates better with time. Additionally accompanied by a more intense organic matter reduction, which results a relative enrichment of phosphorus content.

Redox potential

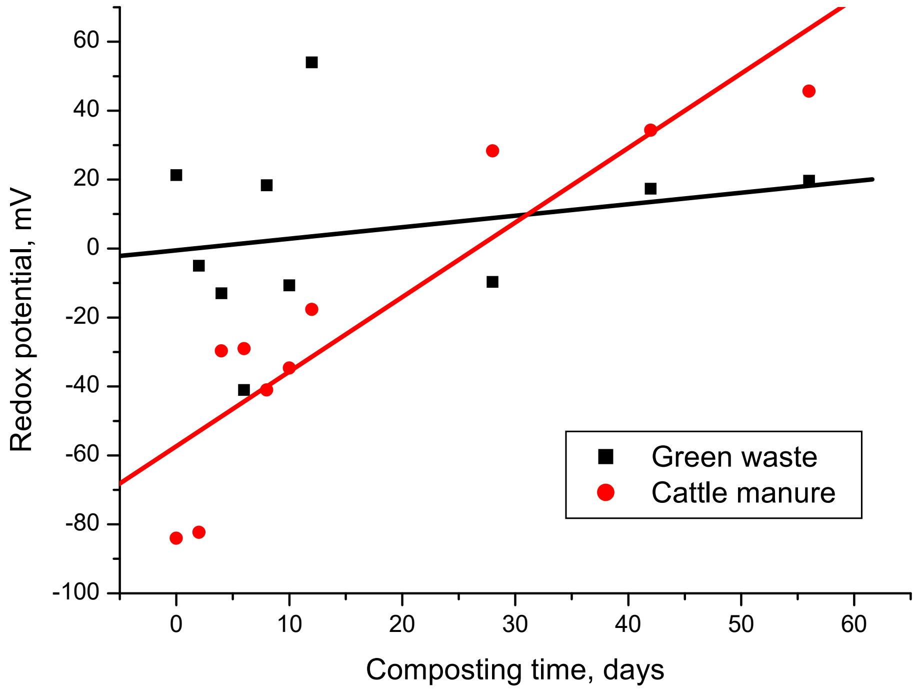


Figure 4: Changes of redox potential in composts as a function of duration

	Intercept	Error	Slope	Error	Correlation
Green waste	-0.47222	11.71342	0.33366	0.4763	0.24041
Cattle manure	-57.33681	8.81836	2.16291	0.35858	0.9054

Table 3: Analysis of functions fitted to redox potential of tested composts

Increasing redox potential can be detected for both cases during composting (Figure 4), in case of cattle manure compost I measured a remarkable increase with a quite good correlation during oxidative biodegradation, however in case of green waste I found a singnificantly lower slope and correlation was also not close (Table 3). The difference in the redox potential value between the two types of material (green waste, cattle manure) could stem from their diversity. Hence possible that in case of green waste the first (0. day) sampling shows relatively great redox potential. We started the cattle manure composting with a practically freshly extracted material, in which the high moisture content could possibly be the result of anaerobic parts which could be the cause of low redox potential in the beginning of process. The change in redox potential showed a more significant change during the study.

Optical examination of alkaline extracts
The evolultion of E_4/E_6 ratio of composts

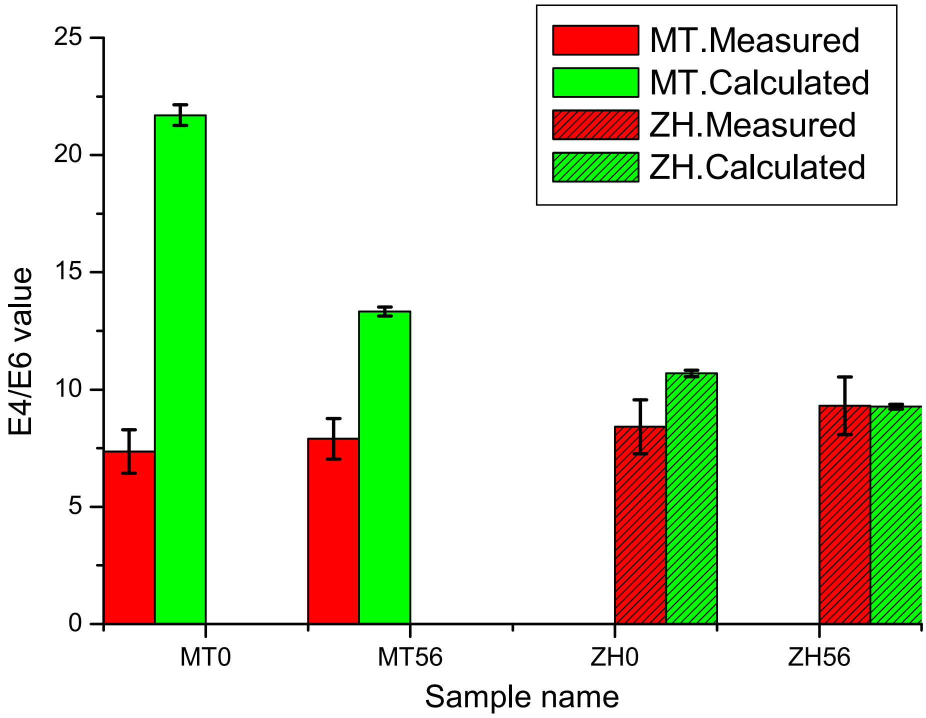


Figure 5: The measured and calculated E_4/E_6 values of samples as a function of composting duration

*MT-Cattle manure, ZH-green waste, Mért- E_4/E_6 ratio determined from the mean absorbance at 465 and 665 nm, Számolt-E_4/E_6 ratio calculated with the formula $e^{\frac{200}{t1}}$

The slight decrease that was measured in the E_4/E_6 ratio by Scheffer, 1954; Welte, 1955; Chen et al., 1977 cannot be significantly proved with statistics. It is easily detectable that opposed to our awaitings the 56 days of composting does not remarkably affects non of the materials in terms of determining the E_4/E_6 (465/665 nm) values of alkaline extracts as a function of spectra. In my case, it can be concluded that (within 56 days) the measured E4 / E6 values cannot be used to track the progression of composting, so this parameter cannot be used as an indicator of compost maturation. The calculated E_4/E_6 from $e^{\frac{200}{t1}}$ however shows an obvious decrease for cattle manure 21.7-13.3, but it decreased also in case of green waste 10.69-9.27 (Figure 5).

Comparison of spectra of raw materials and samples of the 56. day

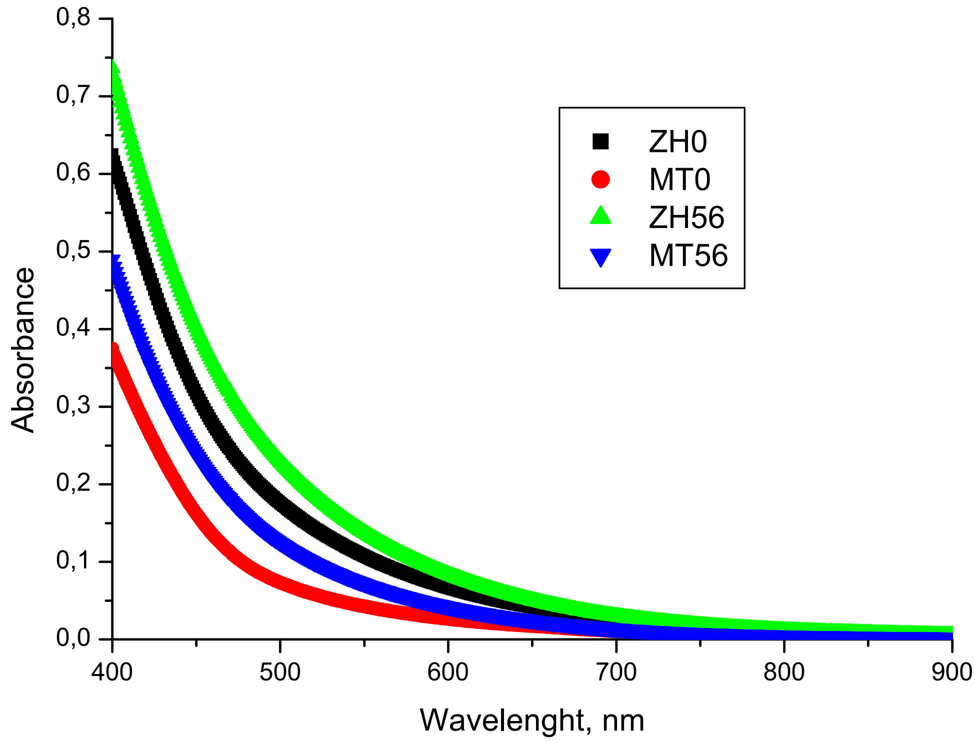


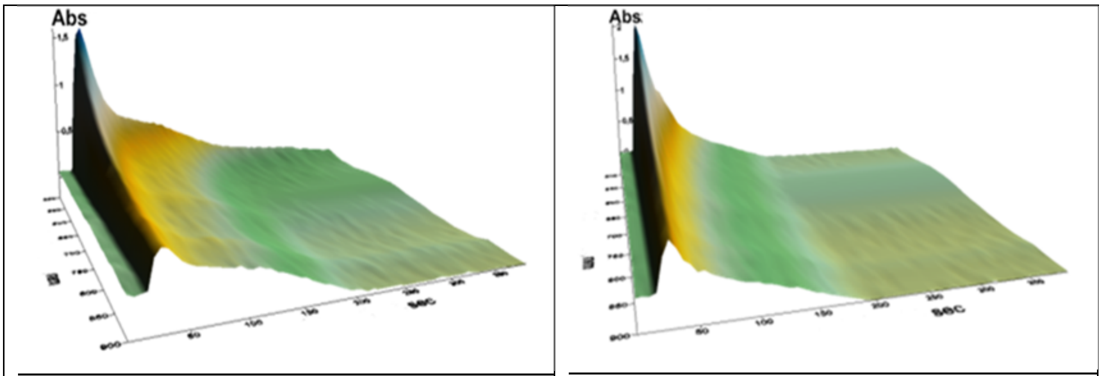
Figure 6: Visible absorption spectra of raw materials measured for alkaline extracts of 56-day compost in accordane with raw materials

*ZH-Green waste, MT-Cattle manure, sample taken on 0-0. day, sample taken on 56-56. day

It is clearly visible on Figure 6 that spectra shows a specific exponential decrease of humus substances as a function of wavelength, the correlation coefficient is always greater than 0.99. Due to the effect of composting the spectra (its absorbance values) shows an upward movement (the parameter), hence the light absorption increases at all wavelengths during composting. Comparing the t1 parameters can be stated a significant increase in case of all raw material during composting, namely the light absorption slightly decreased with the wavelength. The start of humus-like substances' structural element condensation could be the result of detectable greater absorption values at greater wavelength. According to literature data the quantity of fulvic acid increases for 40 days of composting, after stagnates or decreases and the amount of humic acid prevails (Inbar et al., 1989).

Optical examination of hot water percolation based on data of full spectrum
The examination of the effect of raw material

Comparison of treatments of 0. day



MT0 sample	ZH0 sample

Figure 7: The light absorption of MT0 and ZH0 samples from hot water extraction as a function of flow-through time and wavelength

*MT0-0. day sample of cattle manure, ZH0-0. day sample of green waste

Comparing the flow-through and light absorption figures (Figure 7) it can be seen that along the axis of wavelength in the examined wavelength range the light absorption decreases monotonically and evenly. This tendency is true for all tested flow curve and is consistent with the statement of Sebők et al., (2018) that can be described with the context of exponential decline. Similarly, along the axis of time there is a detectable monotonous decrease, however the decline is not continuous, the rate of decline in the range of 100-150 seconds is apparently less than expected from regular steady change.

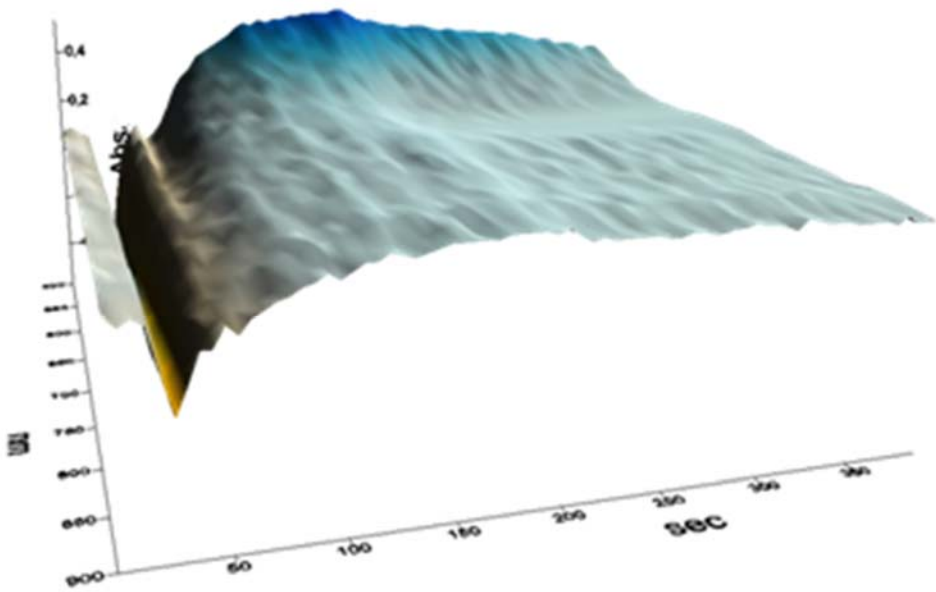


Figure 8: The light absorption difference of MT0 and ZH0 samples from hot water extraction as a function of flow-through time and wavelength

*MT0-0. day sample of cattle manure, ZH0-0. day sample of green waste

Figure 8 is suitable for the examination of difference between the two raw materials which was prepared as followed. I subtracted the appropriate points of green waste from the cattle manure compost in the context of spectrum-time, and I represented this difference on a 3D figure. It can be clearly seen that deviation is in the range where the time course of the spectra differs the most from the exponential decrease corresponding to the dilution. But I have found a difference in another range, the light absorption of the cattle manure sample has always surpassed that of green waste, which means that cattle manures is a hot water soluble raw material which is light absorbing, the color organic matter content is greater than in green waste. In the low-absorption range, the greatest detectable difference was found in the light absorption of cattle manure and green waste.

Examination of the effect of composting in case of cattle manure sample

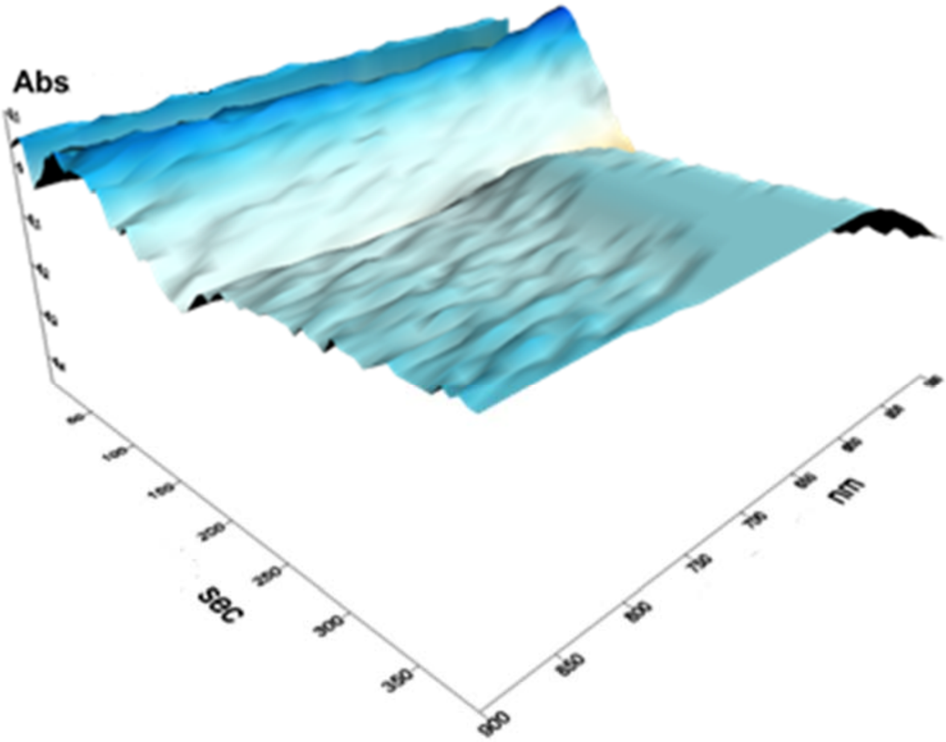


Figure 9: The light absorption difference of MT56 and MT0 samples from hot water extraction as a function of outflow time and wavelength

*MT56.- 56. day sample of cattle manure, MT0- 0. day sample of cattle manure

Figure 9 is suitable for examining the difference due to composting which was prepared as followed. I subtracted the appropriate points of cattle manure compost (56. day) from the cattle manure raw material in the context of spectrum-time, and I represented this difference on a 3D figure. It can be clearly seen that by examining the spectrum in the context of wavelength, that one maximum value can be found between the range of 550 and 650 nm. This outflow time starts at 100-150 sec and lasts until the end of percolation time. Examining in the context of outflow time, we find that the starter stage of outflow there is a periodic difference between the compost and raw material, later the two flow curve do not differ. So can be concluded that difference in light absorption is due to composting and the changes of rapid organic matter solubilisation in case of cattle manure.

Examination of the effect of composting on green waste

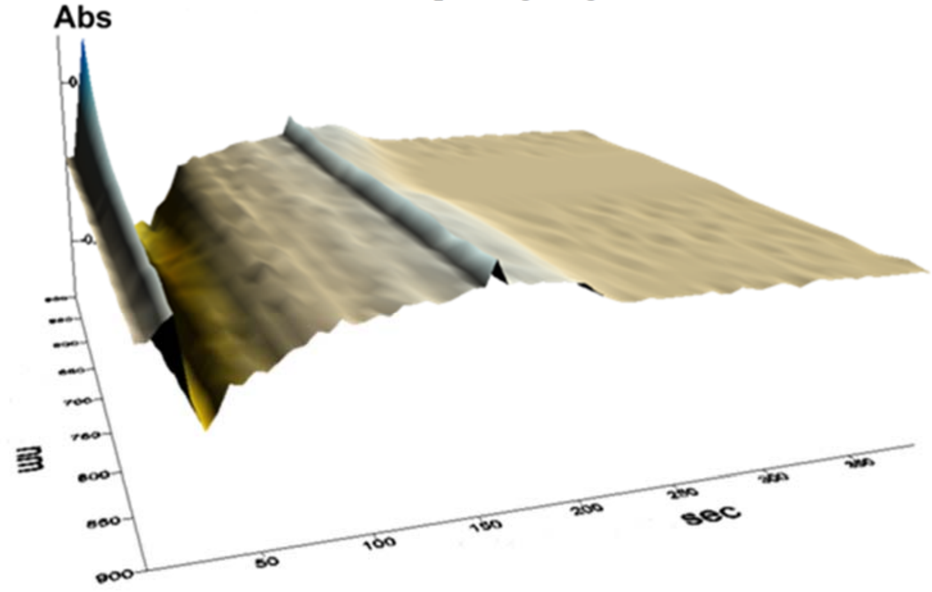


Figure 10: The light absorption difference of ZH56 and ZH0 samples from hot water extraction as a function of floe-through time and wavelength

*ZH56-56. day sample of green waste, ZH0-0. day sample of green waste

I calculated the spectra differences between the measured raw material during solubilization and the mature compost from green waste. The run of curves shows that in the initial stage (start of solubilization) the compost presents less absorption values compared to the raw material, which can be proved by the difference of required duration of organic matter solubilization for more mature compost and raw material, afterward follows a slight increase in the middle of duration for solubilization. After the measurable optical differences are gradually disappearing between the two types of mature material (Figure 10).

The optical examination of hot water percolation kinetics

I have examined the absorption differences by testing the continuously passing hot water as a function of outflow time and the quantity of passing hot water indirectly. At all measured wavelentgths the run was similar to each other, but in the absorbance the obtained run has a different size as a function of wavelength.

I present the analysis of raw material and fully mature compost (56 days compost) in terms of light absorption change at 660 nm wavelength.

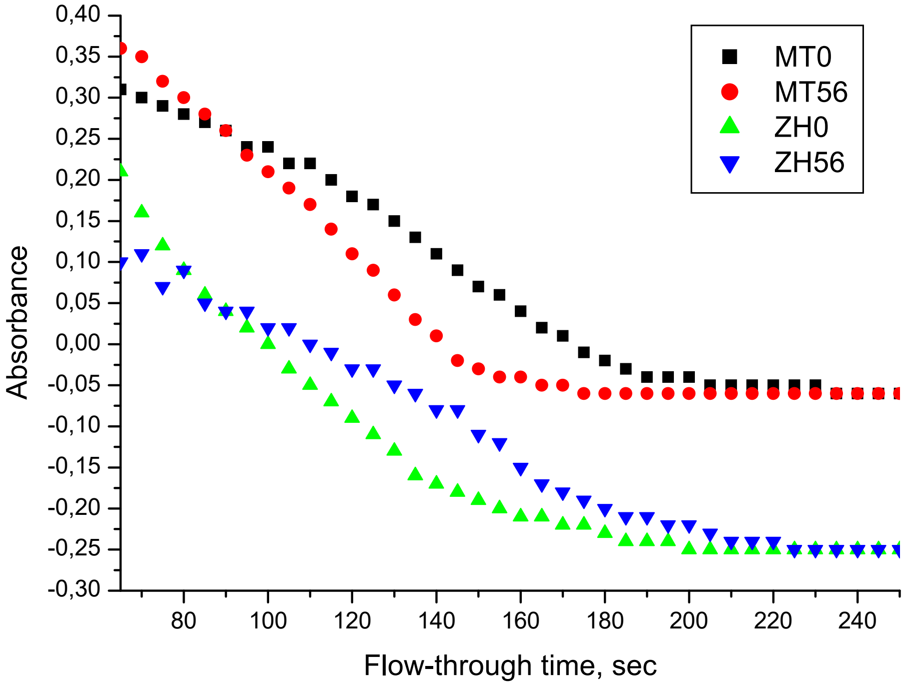


Figure 11: The absorbance change of examined composts (and raw materials) as a function of duration at 660 nm-en

*MT-cattle manure, ZH-green waste, sample taken on day 0-0, sample taken on day 56-56.

Figure 11 shows that run of curves are similar, however differ from each other, hence it can be concluded that both raw material and composting influences the hot water solubilization of materials which are light absorbing. Theoretically these curves must have shown an exponential decrease, because when we continuously alkalize a soluble, light absorbant containing material (finite amount), the process can be described with primary kinetics, so with an exponential function (Czinkota, 1994).

This case it can be seen that curves are monotonously declining, but do not presenting the run of clearly primary kinetics. Hence, another process must be assumed which affects the leaching (alkalization). I have assumed that a process takes place during leaching parallel which occasionally the cause of forming some light absorbing material due to longer cooking, and which has a similar absorption curve as humus-like substances. The explanation can be that particles or fulvic acid nature materials (inside the original fibers in case of raw compost) can only be leached if the containing particle or fiber is swelling enough. The particle and fiber size are obviously not the same, but I assume that the size of granules are following the Gaussian distribution normally, because they were formed either naturally or during sie reduction. Accordingly it can be assumed that granule sizes are influencing the full swelling of granules, namely influencing the solubilization of internal materials, so these processes can be described by a Gaussian function. Based on this, the whole process can be described as the sum of the exponentially decreasing release of free and soluble organic molecules and the dissolution of the swollen particles in the manner described by the Gaussian function.

The r2 value of the matched function was always greater than 0.99, indicating a close correlation. The function used can be described by the following equation:

$$\boldsymbol{Y = y0 + \frac{A1}{w \cdot \sqrt{(\pi/2)}} \cdot e^{-2\cdot\left(\frac{x-xc}{w}\right)^2} + A2 \cdot e^{-k\cdot x}}$$

The above function is graphically shown in Figure 12, the ZH0 original measured points marked with black, the full function (red), and the components with the Gaussian function (blue), the exponential (green).

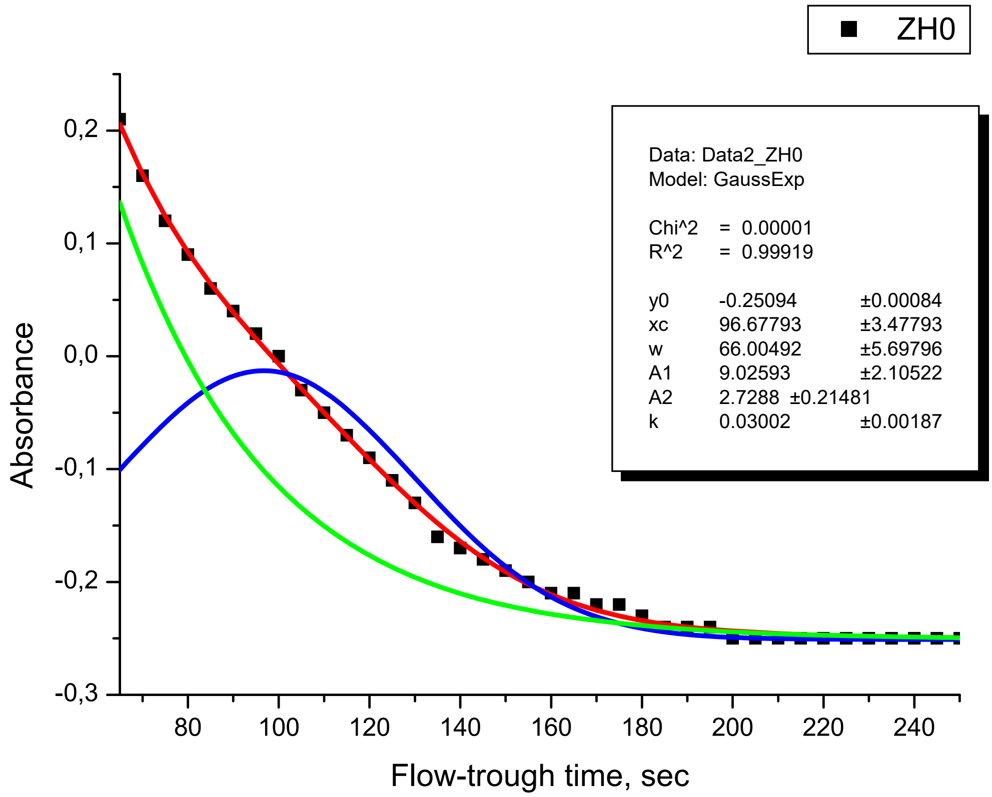


Figure 12: The exponential function fitted to the originally measured points and the Gaussian dissolution function and a fitted function created by the sum of functions in case of sample ZH0 at 660 nm

*ZH0-green waste sample taken on the 0. day

By examining the fitting parameters I have found that raw material and composting have not resulted changes in the exponential function parameters which means that easily soluble organic matter fraction is not dependent on either composting or raw material.

However, the Gaussian function parameters have shown significant differences.

Based on the similarity between the two graphs, the values are analyzed by regression analysis. The result is shown in the following figure:

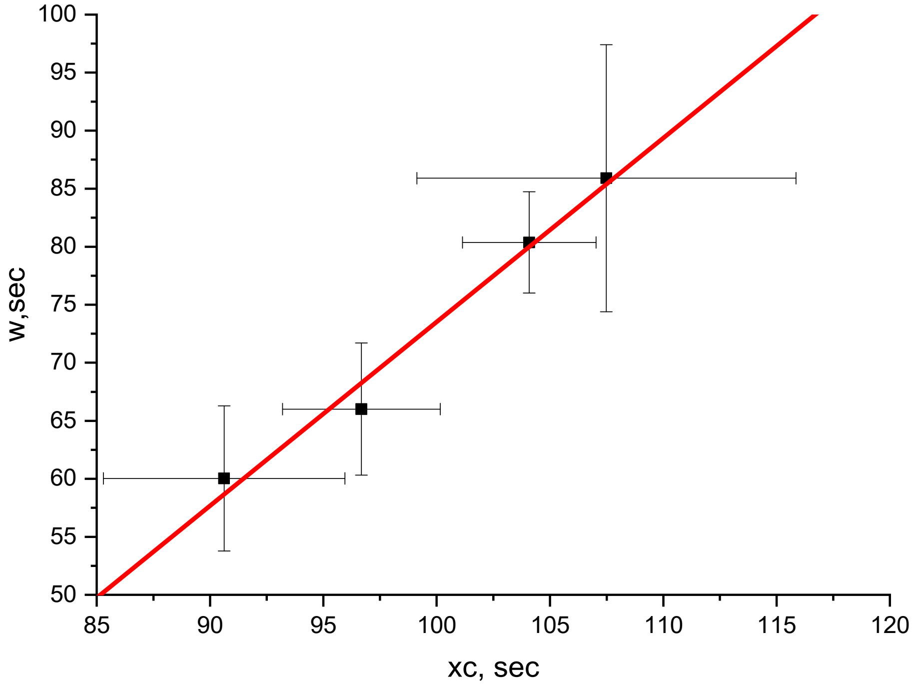


Figure 13: Regression of the w and xc parameters of the Gauss curve fitted to the release curve of each sample

*xc- the release delay value of Gaussian curve, w-standard deviation value of Gaussian curve

It is clearly visible on Figure 13 and parameter values, that correlation is very close between the measured Gaussian parameters, so the greater the delay of solubilization, the greater the standard deviation. The 0.99 correlation is very tight and the 1.58 slope indicates that an approx. 1,5x standard deviation change holds a unit.

New scientific results

1. The samples' (taken on the 0. and 56. day) spectra made with alkaline extraction shows the typical characteristics of humic substances which results exponentional decrease as a function of increasing wavelength (400-900 nm). The correlation coefficient of the fit is always greater than 0.99. The absorbance increases due to the composting.

2. The E_4/E_6 ratio calculated from the spectra by the formula $e^{\frac{200}{t1}}$ shows the expected decreasing tendency as the maturation progresses, while in the case of direct measures and division calculations this regularity is not observed.

3. The raw materials of examined composts were sampled on the 0. and 56. day with hot water extraction and it can be noted that absorption measured at 660 nm implies that both raw material and maturation have an influence on the light absorption of hot water soluble materials.

4. In case of hot water extraction at 660 nm I have developed a function to describe the absorption curve measured at the flow time, which defines the dissolution of the easily soluble hot water (HWP) fraction with an exponential curve and with the Gaussian function as a result of the dissolution due to the effect of the conversion. The r2 value of the function is always greater than 0.99, which refers to a close correlation. In the fitting parameters of the exponential function, neither the raw material nor the composting causes a significant difference, hence the easily soluble organic matter fraction does not depend on either the process or the raw material, while the Gaussian function parameters (w, xc) show significant differences. There is a very close correlation (0.99) between the above parameters. This shows that the raw material primarily influences the organic matter fraction that becomes soluble during HWP.

Conclusion and suggestions

It can be noticed from the examination that during the composting of green waste and cattle manure, that obtained parameters are dependent on both raw material and composting time, but in different ways.

Only few scientists have addressed the photometrical examination of composts, the kinetic analysis of determined processes and their mathematical modelling. Similarly, only subfields of the subject were covered abroad.

During my research I have examined the process of composting in case of 2 different raw material, beside the basic characterstics I have also determined the spectroscopic features changes from alkaline and hot water (HWP) extractions.

It would be worth performing the spectrophotometrical analysis of hot water (HWP) and alkaline extractions in case of other types of materials (animal origin by-products, food waste, sewage sludge, municipal, mixed waste, etc.), by obtaining samples during composting.

The analysis of continuous HWP extraction could be improved by preventing the formation of microbubbles formed during the extraction (disturbing the measurement) or by post-treatment of the sample for this purpose. By doing so, the hot water solution should be run in an open system at a certain stage and the temperature of the cuvette should be reduced to a significant extent. This would make it possible to measure at lower wavelengths (e.g. 440 nm).

It would also be worth widening the spectrum of the wavelength used for the study.
In addition to the spectrophotometric method, useful information could be obtained by linking the analysis of samples with other modern analytical methods (GC, HPLC). Thus, the method could be validated.

Related publications

1. Peer-reviewed research articles

1.1. With impact factor (according to WEB OF SCIENCE), in English:
1.1.1. Hungarian publischer:
1.1.2. International publischer:
1.2. In English, without IF
1.2.1. Hungarian publisher

Kovács D., Kardos Gy., Füleky Gy.
Effects of acid treatment and composting on bones used as fertilizer
ACTA AGRONOMICA HUNGARICA 55. szám p.115-123. (2007) **(7 points)**

Kovács D., Rózsáné Szűcs B., Füleky Gy.
Determination of the maturity of composts based on oxygen consumption, carbon-dioxid production and a self-heating test
BULLETIN OF THE SZENT ISTVÁN UNIVERSITY
Editor: Dr. Mézes M., Gödöllő ISSN 1586-4502, 100-113. pp. (2007) **(7 points)**

Kovács D., Aleksza L., Füleky Gy.
Determination of compost maturity using the hot water percolation (HWP) method.
COLUMELLA Vol. 4. Number 2. 41-46. pp. (2017) **(7 points)**

Independent quoter: 1 Összesen: 1
Hunyadi G., Tamás J. (2010): Hőfelvételek és interpolációs eljárások alkalmazhatósága komposzt-prizmák felszíni hőmérsékletének vizsgálatára, Acta Agraria Kaposváriensis, Vol 14 No 3, 293-302 pp. **(1 point)**

1.2.2. International publisher
1.3. In Hungarian, without IF

Kovács D., Kardos Gy., Füleky Gy.
A feltárás és a komposztálás hatása a csontok trágyaszerként történő alkalmazhatóságára
AGROKÉMIA ÉS TALAJTAN 54. száma. p. 427-439. (2005) **(5 points)**

Kovács D., Rózsáné Szűcs B., Füleky Gy.
Komposztok érettségének meghatározása oxigénfogyasztás, szén-dioxid termelés mérésével és önhevülési teszttel
AGROKÉMIA ÉS TALAJTAN 56. kötet, 2 szám p. 301-317. (2007) **(5 points)**

Kovács D., Füleky Gy.
A komposztérettség és meghatározásának módszerei (szemle)
AGROKÉMIA ÉS TALAJTAN 65. kötet, 1 szám p. 135-160. (2016) **(5 points)**

2. Professional full text article,

2.1. Professional full text article

Kovács D.
A komposztálás háttéripara
HULLADÉKSORS III. évfolyam 12. szám. p. 13-14. (2002) **(2 points)**

Kovács Dénes
A komposztálás gépészeti háttere
BIOHULLADÉK I. évf. 1. szám. 21-23. oldal (2006) **(2 points)**

Kovács Dénes
Komposzt-tea szerves alapú termésnövelő anyag
BIOHULLADÉK I. évf. 3. szám. 24-27. oldal (2006) **(2 points)**

Kovács Dénes
A komposzt-szerű frakció
BIOHULLADÉK II. évf. 1. szám. 26-31. oldal (2007) **(2 points)**

Kovács D., Rózsáné Szűcs B., Füleky Gy.
Komposztok érettségének meghatározása oxigénfogyasztás, szén-dioxid termelés mérésével és önhevülési teszttel
BIOHULLADÉK Tudományos melléklet 2 évf. 3 szám. 20-24. (2007) **(2 points)**

Kovács D., Kiss Zs. L., Gulyás M, Füleky Gy.
A komposzt érettség vizsgálata forróvizes extrakcióval (HWP)
BIOHULLADÉK Tudományos melléklet 7. évf. 1. szám 15-17. (2007) **(2 points)**

György Füleky, Dénes Kovács, László Aleksza
Evaluation of compost maturity using hot water extracted (HWP) carbon and nitrogen
BIOHULLADÉK Tudományos melléklet 10. évf. 2. szám 17-20. (2016) **(2 points)**

4. Conference proceedings with ISBN, ISSN or other certification
4.1. Full text article in Foreign language, peer-reviewed

Aleksza L., Dér S., Kovács D., Füleky Gy.
Soil improvement composted agricultural waste materials, poster
ESSC 4. nemzetközi konferencia. Budapest (2004) **(5 points)**

Kovács D., Füleky Gy.
Nutrient release from compost material with hot water percolation (HWP) method, poster
10. International Symposium on Soil and Plant Analysis conference. Budapest. (2007) **(5 points)**

György Füleky and Dénes Kovács
Evalutation of compost maturity by hot water extracted (HWP) carbon
8th International conference ORBIT, Rennes, 6 pages (2012) **(5 points)**

4.2. Full text article in Hungarian, peer-reviewed

5. Conference proceeding without certification
5.1. Full text article in Foreign language
5.2. Full text article in Hungarian
5.3. One page summary in Foreign language or Hungarian

Kovács D.
Comparative examination of composts made by different treatment, TDK dolgozat - absztrakt
XXV. Országos Tudományos Diákköri Konferencia Agrártudományi Szekció előadásainak összefoglalói, Nyugat-Magyarországi Egyetem, Sopron p. 236. (2001) **(1 point)**

Füleky, Gy., Kovács, D., Aleksza L., Dér S.
Use of the hot water percolation (HWP) method for compost analysis, Poszter, Innovatív hulladékgazdálkodási technológiák – Követelmények az Európai Unió tagállamai és a csatlakozni kívánó országok részére c. konferencia Gödöllő. (2002) **(1 point)**

Füleky Gy., Kovács D.
Composting of boneflour and chemicaly, biologicaly testing of it's end product
Lippay János - Ormos Imre – Vas Károly scientific symposium, section of natural resources p. 587. (2003) **(1 point)**

Füleky Gy., Kovács D., Aleksza L., Dér S.
Use of hot water percolation (HWP) method for compost analysis, abstract ORBIT conference p. 267-275. (2003) **(2 points)**

Aleksza L., Dér S., Kovács D., Füleky Gy.
Soil improvement composted agricultural waste materials, poster abstract ESSC 4. international conference p. 274-277. (2004) **(2 points)**

Füleky Gy. – Kovács D.
Composting of boneflour and chemicaly, biologicaly testing of it's end product, abstract,
VI. Nemzetközi élelmiszertudományi konferencia, Szeged, 2004 06 20-21. (2004) **(1 point)**

Aleksza L., Kovács D.
Investigation of the biodegradability of paper sludge, abstract
COST Action E26 Effective solutions to reduce the impact of waste arisings from papaermaking program, Solid waste management in the papermaking prevention, creation of new products and energy recovery workshop. (2005) **(2 points)**

Kovács D. - Füleky Gy.
Nutrient release from compost material with hot water percolation (HWP) method, poster abstract
10. International Symposium on Soil and Plant Analysis, Budapest. p. 143. (2007) **(2 points)**

Kovács D.
Különböző eljárással készült komposztok összehasonlító vizsgálata TDK dolgozat - absztrakt
XXV. Országos Tudományos Diákköri Konferencia Agrártudományi Szekció előadásainak összefoglalói, Nyugat-Magyarországi Egyetem, Sopron p. 258. (2001) **(1 point)**

Füleky Gy., Kovács D.
A csontliszt komposztálása és a komposztok kémiai és biológiai tesztelése, előadás absztrakt
Szent István Egyetem, Budai Élelmiszertudományi, Kertészettudományi és Tájépítészeti, - védelmi és -fejlesztési karai által szervezett Lippay János - Ormos Imre – Vas Károly Tudományos Ülésszak p. 586. (2003) **(1 point)**

References

Bannick, C.G. und W. Ziechmann (1991): Huminstoffbildung während der Kompostierung. Z. Pflanzenernähr. Bodenkund. 154:233-236.

Bernal, M. P., Navarro, A. F., Sánchez-Monedero, M. A., Roig, A. és Cegarra, J., (1998): Influence of sewage sludge compost stability and maturity on carbon and nitrogen mineralization in soil. Soil Biology and Biochemistry. 30: (3) 305–313.

Brewer, L. J. & Sullivan, D. M., (2001): A quick look at quick compost stability test. Biocycle. 42. 53–55.

Butler, T. A., Sikora, L. J., Steinhilber, P. M. & Douglass, L. W., (2001): Compost age and sample storage effects on maturity indicators of biosolids compost. Journal of Environmental Quality. 30. 2141–2148.

Chen, Y., N. Senesi, And M. Schnitzer (1977): Information provided on humic substances by E4/E6 ratios. Soil Sci. Am. J. 41:352-358 p

Czinkota I. (1994): A talajok forróvizes extrakciója. Egyetemi doktori értekezés. Gödöllő.

Inbar, Y.,Y. Chen, Y. Hadar. (1989): Solid-state carbon-13 nuclear magnetic resonance and infrared spectroscopy of composted organic matter. Soil Sci. Soc. Am. J.53:1695-1701.

Jakusné Sári Sz. – Forró E. (2006): Composted and natural organic materials as potential peat-substituting media in green pepper growing. International Journal of Horticultural Science 12 (1): 31-35.

Jiménez, E. I. & Garcia, V. P., (1989): Evaluation of city refuse compost maturity. A Review. Biological Wastes. 27. 115–142.

Kovács, D. és Füleky Gy. (2016): A komposztérettség és meghatározásának módszerei, Szemle. Agrokémia és Talajtan. 65. 135-160.

Laga, (1984): Qualitatskriterien und Anwendungsempfelhungen für Kompost aus Müll und Müllklarschlamm. (Quality criteria and application recommendations for compost from waste and sludge) Merkblatt 10 der Landerarbeitsgemeinschaft Abfall. Erich Schmidt Verlag. Berlin.

Nagy, P. T., Kátai, J., Szabó, Z., Nyéki, J. (2008): A talaj felvehető nitrogén-, foszfor- és káliumkészletének változása integrált almaültetvényben beállított talajtakarásos kísérletben, Talajvédelem különszám 481-488.

Said-Pullicino, D., Kaiser, K., Guggenberger, G. & Gigliotti, G., (2007): Changes in the chemical composition of water-extractable organic matter during composting: Distribution between stable and labile organic matter pools. Chemosphere. 66. 2166–2176.

Scheffer, F., (1954): Neuere erkenntnisse in der humusforschung. Congr.
Sebők, A., Czinkota, I., Nyiri, B., Bosnyákovics, G., Gulyás, M., Dálnoki, A. B. (2018): A talaj szervesanyag minőségének vizsgálata UV-VIS spektrumban – az exponenciális illesztés módszere (EFA), Növénytermelés 67. 59-71.

Sellami, F., Hachisha, S., CHtourou, M., Medhioub, K., Ammar, E., (2008): Maturity assessment of composted olive mill wastes using UV spectra and humification parameters, Bioresource Technology 99: 6900-6907.

Song C., Li M., Xi B., Wei Z., Zhao Y., Jia X., Qi H., (2015): Characterisation of dissolved organic matter extracted from the bio-oxidative phase of co-composting of biogas residues and livestock manure using spectroscopic method. International Biodeterioration & Biodegradation. 103. 38-50.

Stentiford, E., (2002): The Specific Oxygen Uptake Rate (SOUR) – the English practice. In: The Biological Treatment of Biodegradable Waste – Technical aspects. April 8–April10. Brussels.

The Composting Association, (2001): Large-Scale Composting. A practical manual for the UK.

Welte, E., (1955): Neuere Ergebnisse der Humusforschung. Angewandte Chemie. 67: 153-155.

Xi, B.D., He, X.S., Wei, Z.M., Jiang, Y.H., Li, M.X., Li, D., Li, Y., Dang, Q.L., (2012): Effect of inoculation methods on the composting efficiency of municipal solid wastes. Chemosphere 88, 744-750.

http1. https://net.jogtar.hu/jogszabaly?docid=a0300023.kvv Keresőprogram: Google. Kulcsszavak: 23/2003 kvvm Lekérdezés időpontja: 2019.02.11.

http2. https://net.jogtar.hu/jogszabaly?docid=A0600036.FVM Keresőprogram: Google. Kulcsszavak: 36/2006 fvm Lekérdezés időpontja: 2019.02.11.