Determination of compost maturity using the Hot Water Percolation (HWP) method

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Abstract: Maturity is one of the parameters that needs to be examined when producing composts. The present paper aims to evaluate whether the Hot Water Percolation (HWP) method elaborated for soil analysis can be used to determine the maturity of composts. The methods involves percolating boiling water through dry, ground compost samples, followed by the measurement of the dissolved carbon and mineral nitrogen contents and the spectral properties of the solution. Two groups of compost samples were examined. In one group the above parameters were recorded throughout the 42-day maturing process, while in the other group these parameters were measured on 7 samples judged to be mature and 5 judged to be fresh. The HWP-soluble NH_4-N/NO_3-N ratio was less than 0.16 in mature composts; for both compost groups the HWP-C value was less than 100 mg L^{-1}, absorbance at 254 nm was 1.0-2.0 cm^{-1}, the E4/E6 ratio was generally less than 2.0 and the SUVA (specific UV absorption) value at least 1.4 but generally higher, depending on the initial materials. The extracts obtained using the HWP method provide a good demonstration of the maturity stages in the composting process in spite of the speed of extraction.

Keywords: compost maturity, E4/E6 ratio, HWP soluble carbon, NH_4/NO_3-N, spectral properties

Introduction

Compost maturity has been determined with different agents using a variety of indices based on the physical, chemical, biological, biochemical and humification characteristics of organic matter (Körner et al. 2003). Of all these indices, related to the water-soluble fraction of the organic matter because most of the biochemical transformation of organic matter take place in this fraction during composting. The water-soluble carbon content, the C/N ratio, the nitrate content, the pH and the temperature were found to be important factors affecting microbial community structure and metabolic pathways (Zhang et al. 2011; Sundberg et al. 2004). The intensity of organic matter degradation and the evolution of water-soluble compounds depend on the kind of material used in the starting mixture. Key indicators include water-soluble organic carbon (C_{ow}), and the ratios of water-soluble carbon to water-soluble organic nitrogen (C_{ow}/N_{ow}) and water-soluble organic carbon to total organic nitrogen (C_{OW}/N_{OT}). The values proposed for indicating maturity are the following: C_{OW}<0.5-1.7%, C_{OW}/N_{OW} 5-6, C_{OW}/N_{OT} <0.40 (0.55), (Sanchez-Monedero et al. 2001; Bernal et al. 1998). The wide variation in recommendations for these parameters suggests that the value of WSC should be established based on compost feedstock (Benito et al. 2009). The ratio of inorganic forms of nitrogen has been used as a criterion for assessing the maturity of compost. A NH_4/NO_3 ratio of <1 at the end of the process suggests that the final compost has reached maturity (Bernal et al. 1998; Aparna et al. 2008).

E_4/E_6 has long been considered to reflect the degree of condensation of the aromatic nucleus of humus, thus indicating its maturity (Aparna et al. 2008). With an increase in composting time, the E_4/E_6 ratio decreases significantly, suggesting that carbohydrates and quinones have been oxidized and bound to methoxyl groups and/or aliphatic side chains in humic substances. A suitable degree of maturity and stability is denoted by a lower ratio of E_4 to E_6 at the end of the composting process (Sellami et al. 2008).

Usually UV absorption of bulk water-extractable organic matter samples was measured at 254 nm. The absorbance was normalized to the concentration of dissolved organic C, giving the specific UV absorption ($SUVA_{254}$), which serves as an indicator of the aromatic character of organic matter. The organic C content of water-extractable organic matter decreased significantly from 6.0 mg L^{-1} in the initial material to 1.5 mg L^{-1} during the 250-day composting period

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towards the end of the process. The $SUVA_{254}$ values obtained for bulk water-extractable organic matter remained constant during the first 28 days of composting (with an average value of 0.97 L mg^{-1} m^{-1}), but subsequently increased steadily to 1.77 and then to 3.02 L mg^{-1} m^{-1} by days 90 and 250, respectively (Said-Pollicino et al. 2007; Jaffrain et al. 2007).

The present paper aims to evaluate whether the Hot Water Percolation (HWP) method elaborated for soil analysis can be used to determine the maturity of composts. A further aim was to investigate whether the maturity values determined for German composts confirmed the results obtained using the HWP method.

Materials and methods

Compost experiment in Gödöllő

Two groups of composts were used in the experiments. In the first case the maturity of composts prepared at an open composting site at the Waste Management Unit in Gödöllő using the GORE™COVER technology was examined. This is a closed system measuring 1 heap 8×35×3.5 m with forced aeration (blowers on for 5 min every 20 min). The cover used was a PTFE semipermeable membrane which helps to ensure the diffusion of gases but retains heat and steam.

Using this technology the composting process involves 4 weeks of intensive maturing, followed by a further 2 weeks without cover or aeration.

The composting windrow was built from garden, park and home wastes on 10th October and the process was terminated on 21st November. The outside temperature was originally above 10°C, dropping to about 5°C from 15th November onwards.

The sampling times were 0, 2, 8, 16, 21, 30, 37 and 42 days after the establishment of the compost windrow, with a sampling depth of 40 cm.

Investigation of German compost materials

The other group of composts consisted of samples kindly provided by BGK (Bundesgütegemeinschaft Kompost e.V., Köln). Five compost samples were deemed to be "fresh" and seven samples were considered to be "mature" according to the German system of classification, which is based on the Dewar self-heating test *(Table 1. and 2.)*.

Compost analysis

The organic carbon content and spectral properties of the HWP extracts were determined. Hot water percolation (HWP) is a new and easily applicable soil extraction method (Füleky and Czinkota 1993) which was adapted for compost analysis (Füleky et al. 2003). In the course of hot water extraction, 5 g dry, ground compost was placed in the sample holder, after then boiling water was poured onto the compost and the resulting solution was collected as five 100 cm^3 samples. Approx. 1 min was required to obtain 100 cm^3 extract.

The extractable, hydrolysable and readily soluble elements and compounds are extracted (102-105°C) at 120-150 KPa during hot water percolation (Takács and Füleky 2003). The organic carbon, nitrate-N and ammonium-N contents of each extract were determined by distillation. The chromic acid test was used to

Table 1. Fresh compost samples composition of German composts

Sample	Ratio v/v%	Composition
5/1	50:50	scb/gpw
5/2	70:30	scb/gpw
5/3	90:10	scb/gpw
5/4	70:20:10	scb/gpw and paper
5/5	50:50	scb/gpw

scb: separately collected biowaste; gpw: garden or park waste

Table 2. Mature compost samples composition of German composts

Sample	Ratio v/v%	Composition
7/1	15:85	ssw/ gpw
7/2	70:30	ssw/ gpw
7/3	80:20	ssw/ gpw
7/4	80:20	ssw/ gpw
7/5	70:30	ssw/ gpw
7/6	100	gpw
7/7	75:25	ssw/ gpw

ssw: sewage sludge, sawdust, wood shaving; scb: separately collected biowaste; gpw: garden or park waste

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determine the carbon content, while the optical density was measured at 254, 465 and 665 nm. Except of ∑ HWP-C content, the analysis of all parameter were determined from first 100 cm^3 of extract. 2 repetitions were used in the experiments. The statistical method used was analysis of variance.

Results and Discussion

Gödöllő compost materials

A first-order kinetic function was fitted to the C content determined from hot water extracts of composts at various stages of maturity and to the quantity of water percolated. Then the parameters of the function were determined, including the maximum extractable C content (∑ HWP-C), which declined substantially as composting *proceeded (Figure 1. and Table 3.)*. Data in the table marked HWP-C represent the C concentration found in the first 100 cm^3 portion.

In the case of the compost samples are shown in *Table 3*. the quantity of HWP-C was far higher in incompletely matured samples than in those judged to be mature. The amount of total organic carbon significantly decreased during the composting process *(Table 3.)*. When the HWP-C content decreases during maturation, it means that the amount of fulvic acids also

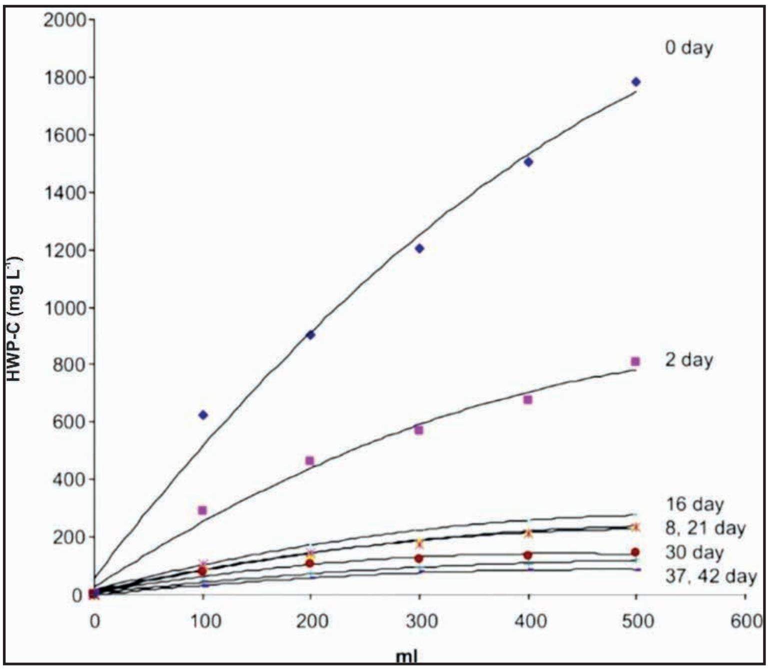

Figure. 1. First-order kinetics of organic carbon release during hot water percolation of compost samples during the composting process. (SzD5% (0 day): 127; SzD5% (2 day): 74; SzD5% (8 day): 95; SzD5% (16 day): 37; SzD5% (21 day): 68; SzD5% (30 day): 48; SzD5% (37 day): 25; SzD5% (42 day): 10.)

Table 3. Hot water extracted (HWP)-C and the spectral properties of Gödöllő compost materials

Days	Org.-C	HWP-C	Σ HWP-C	254 nm	465 nm	665 nm	SUVA	E4/E6
	%	mg L^{-1}	mg L^{-1}	cm^{-1}	cm^{-1}	cm^{-1}	L mg^{-1} m^{-1}	
0	45.40	605.0	1910	6.71	0.310	0.062	1.11	5.11
2	41.02	289.0	807	3.05	0.210	0.056	1.06	3.79
8	20.89	97.6	240	1.52	0.096	0.026	1.56	3.62
16	21.51	133.0	285	1.43	0.144	0.035	1.34	3.21
21	18.78	108.0	233	1.39	0.120	0.044	1.28	2.70
30	20.47	75.7	145	1.15	0.083	0.030	1.53	2.73
37	11.26	49.3	121	1.59	0.075	0.026	3.24	2.80
42	11.83	27.9	86	0.92	0.044	0.025	3.46	1.74
SzD5%	2.13	17.54	29.94	0.29	0.05	0.05	0.44	0.88

decreases. At the same time the amount of humic acid increases (however the method is not able to measure that). Thus the decrease of the fulvic acid suggests its transformation, which means the increase of humic acid, and this process goes with maturity (Sugahara & Inoko, 1981; Inbar et al.1990). Additionally, the hot water-soluble HWP-C content decreased from 605 mg L^{-1} on the day 0 of composting to 27.9 mg L^{-1} on the 42nd day *(Table 3.)*. There was a strong positive correlation between the HWP-C content of the first 100 cm^3 fraction and the sum of the 5 x 100 cm^3 fractions (R=0.99), which means that it was sufficient to measure the carbon content and spectral properties of the first HWP fraction only. The measured HWP-C content is naturally less than the values reported by other authors (0.5-1.7%) (Benito et al. 2009; Sellami et al. 2008), because hot water percolation is a rapid method taking only one or two minutes. There was a very strong linear correlation between absorbance at 254 nm and the HWP-C content of the first 100 cm^3 extract and the sum of the 5 x 100 cm^3 fractions (R=0.97, R=0.96), and also between absorbance at 465 and 665 nm and the HWP-C content of the extracts (R=0.95, R=0.79).

First of all, organic molecules degrade as a result of enzymatic breakdown, leading to a large volume of water-soluble C. Then, as composting progresses, the smaller molecules synthesize into macromolecules and become water-insoluble. The absorbance was measured at 254 nm is proportionate to the amount of fulvic acid. Both the HWP-C content was measured in the first 100 cm^3 and the 5 ×100 cm^3 extracts and the optical density was measured at 254 nm, 465 nm and 665 nm indicate a decrease in fulvic acid during the process of maturation *(Table 3.)*.

The SUVA values proved the presence of larger aromatic molecules. The trend seen in Table 3. is very similar to that reported by Said-Pollicino et al. (2007), who noted a sudden increase in SUVA after the 28th day of composting, indicating the maturity of the compost *(Table 3.)*.

E4/E6 indicates the proportion of fulvic acid/humic acid. As the process progresses, lower values are obtained. The E4/E6 trend in *Table 3.* agrees with the findings of Sellami et al. (2008): E4/E6 significantly decreases with the stage of maturity (*Figure 2.*).

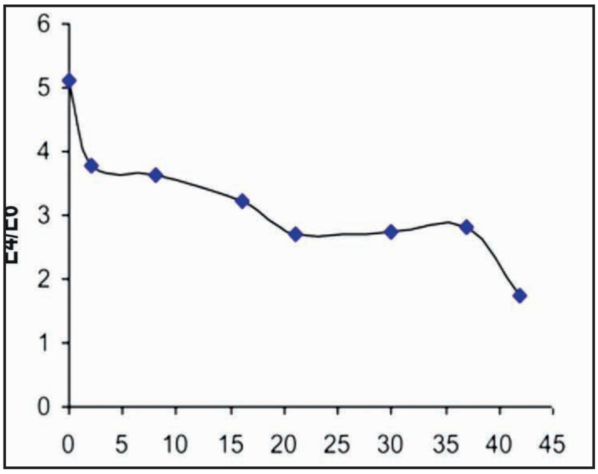

Figure 2. The E_4/E_6 values of HWP extracts at different stages of maturity

German compost materials

The analytical results obtained for composts judged to be mature or fresh on the basis of the Dewar test are presented in *Table 4*. Many parameters examined for these samples were in good agreement with the results of the Dewar test. For instance, the pH was generally higher in fresh compost samples. However, the sample 7/7 is an exception *(Table 4)*. Although it was judged to be almost completely mature, it had very high values of HWP-C content (422 mg L^{-1}) and absorbance at 254 nm (7.844). The NH_4-N content, which is generally much lower in mature than fresh composts, was also high, suggesting that the sample was not fully mature, with a maturity index of 4. On the other hand the NH_4/NO_3-N ratio was less than the values reported by Aparna et al. (2008) and Bernal et al. (1998) (1.0 and 0.1, respectively) in mature samples, but was well above these values in fresh samples. Both the hot water-soluble carbon content and absorbance at 254 nm, which are closely correlated, were higher in fresh samples than in mature composts. However, the SUVA index did not fit the pattern expected from previous experience, as the values recorded in mature samples were only higher than those found for fresh samples in a few cases.

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Table 4. Selected characteristics (hot water extracted (HWP)-C and -N) and spectral properties of German compost materials

Sample	Dewar test		pH	HWP-NH_4-N	HWP-NO_3-N	NH_4-N/NO_3-N	HWP-C	Abs.254 nm	SUVA
Maturity	C°	value		mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	cm^{-1}	L mg^{-1} m^{-1}
7/1	30	5	7.2	2.40	97.94	0.0245	0.025	0.672	1.41
7/2	24	5	7.6	4.96	55.88	0.0887	0.089	1.743	3.48
7/3	26	5	8.3	4.34	39.48	0.1099	0.110	1.114	2.05
7/4	26	5	7.7	4.72	33.84	0.1395	0.139	1.466	1.98
7/5	23	5	7.6	11.26	61.86	0.1820	0.182	1.836	2.08
7/6	24	5	7.9	1.80	17.06	0.1055	0.106	2.05	2.65
7/7	39	4	8.2	55.72	1.00	55.720	421.96	7.844	1.86
5/1	55	2	8.5	23.50	1.00	23.50	23.500	3.355	2.00
5/2	54	2	8.4	28.96	1.00	28.96	28.960	4.456	2.02
5/3	57	2	8.6	26.60	9.20	2.8913	2.891	4.009	2.27
5/4	66	1	7.4	19.43	1.00	19.43	19.430	2.859	1.58
5/5	41	3	8.7	90.21	97.27	0.9274	0.927	3.498	1.95
SzD5%	0.88	0.87	0.54	1.58	3.38	0.0014	3.08	0.43	0.4

Conclusions

It may be concluded that the C content of hot water percolation (HWP) extracts clearly demonstrates the maturity stage of the composting process, in spite of the rapid extraction process. The results obtained for the two groups of composts demonstrate that the carbon content obtained from the hot water extraction method (HWP) is a good indication of the maturing process, similarly to the absorbance recorded at 254 nm, the SUVA index and the E4/E6 values, which decrease in hot water extracts when maturity is reached (with the exception of $SUVA_{254}$, which increases). The NH_4-N and NO_3-N values recorded for the hot water extracts also clearly indicate the maturing process. It should be noted, however, that despite these tendencies, the quality of the raw compost materials also influences the values of these parameters. The simple HWP method (Füleky and Czinkota, 1993) can thus be recommended for a rapid, routine determination of compost maturity.

The main advantage of the HWP method is speed, since compost extracts can be prepared in a couple of minutes and measurements can be made rapidly. The quality of the starting material will influence the results, but as more details and data become available, the method has the potential to generate indicative values about the stage of compost maturity cheaply and rapidly.

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