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Maturity Assessment of Wheat Straw Composts by Thermogravimetric Analysis

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Thermogravimetric analysis in oxidizing atmosphere has been used to characterize composts prepared from wheat straw with different organic and mineral additives. After a wide range of classical parameters were determined for the chemical maturity of composts, plant yield improvement was studied in a greenhouse experiment. It was found that most chemical and agrobiological maturity indices paralleled peak area values in the differential thermogravimetric curves. In particular, the weight loss corresponding to compost material destroyed between 360 and 540 °C showed a very significant correlation with the germination index and the plant yield of the soils amended with compost. As expected, the extent of such thermal effects reflected also the H/C, O/C, and C/N ratios and the lignin content of the composts. Experiments during the methodological optimization of thermogravimetric analyses have shown the importance of removing the compost water-soluble fraction to prevent spurious results, probably due to the effect of salts on thermal decomposition in the lignocellulosic substrate.

Keywords: *Straw; compost; maturity; thermogravimetry*

Wheat straw is the major prime material for compost production in Mediterranean cereal dryland areas.

Whereas straw composting frequently is aimed at the preparation of substrates for mushroom cultivation, the controlled transformation of lignocellulosic crop wastes and their further application in the field are practices focusing on sustainable management of soils exposed to severe risks of erosion and desertification (Lockeretz, 1988). In particular, the progressive decrease of the soil organic matter levels in Mediterranean areas historically subjected to human influence has accelerated in the last half of this century as a consequence of extensive mechanized agriculture (Parr et al., 1990).

Some typical environmental problems—mainly phytotoxicity and biological immobilization of nitrogen—caused by amending soils with not yet matured composts can be evaluated through more or less accurate laboratory tests (Roletto et al., 1985; Riffaldi et al., 1986). Nevertheless, such "maturity indices" are often of limited usefulness, since they report on exact features of the composting system. General criteria should be obtained from analytical techniques to study the compost as a whole, thus avoiding methodological problems—and partial information—of the methods involving compost fractionation. In fact, most maturity indices are based on changes in the composition of the water-soluble fraction, the nitrogen forms, the alkaline extract, etc. In this context, thermal methods have proved to be very useful in the routine analysis of lignocellulosic substrates (Mitchell and Birnie, 1970).

As opposed to the complex information obtained from techniques based on pyrolysis and mass spectrometry (Boon, 1989; Ralph and Hatfield, 1991), the differential thermogravimetric analysis (DTG) of complex substrates led to very simple patterns, the kinetics of the thermal decomposition being empirically interpreted as the progressive destruction of plant biopolymers of different structural stability. The latter feature is of interest in evaluating the resistance to biodegradation that should characterize mature compost and has been used in classical studies to estimate the diagenetic alteration of humus substances and organic rocks (Schnitzer and Khan, 1972; Lévesque and Dinel, 1978; Zimmermann et al., 1987).

In the present study, the results obtained from the DTG of wheat straw composts are compared to those from classical maturity parameters, assuming that the selective preservation of straw biopolymers and the virtual formation of humic-type substances should be quantitatively reflected in the relative extent of the different stages of thermal decomposition.

EXPERIMENTAL PROCEDURES

Laboratory-scale composting of up to 80 substrates prepared with wheat straw was carried out as part of the systematic research on the control of phytotoxicity and nitrogen transformation during composting in the presence of primings and additives traditionally used—or available—in Mediterranean agrosystems (Blanco et al., 1992). Twenty-two samples were selected for the present study.

For compost preparation, wheat straw chopped to 5 mm was moistened to 60% of the WHC and incubated for 3 months in polyethylene containers in a thermostatic chamber at 27 °C. The compost piles were turned every week, while substrate moisture was checked and adjusted when required.

The additives used with the wheat straw corresponded to readily biodegradable materials as well as to mineral or to recalcitrant organic substrates expected to play some role in controlling the N losses or the activity of phytotoxic substances.

Such additives included crop wastes and agroindustrial subproducts (V.SH, vine shoot; G.HK, grape husk; W.DR, wine drawn), protein-rich residues from beer industries (B.BE,

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bagasse; P.BE, powder; R.BE, rootlets; Y.BE, yeast), and miscellaneous additives [C.TL, industrial cellulase from *Trichoderma longibrachiatum;* B.EZ, Bio-Enz (commercial priming)]. Other additives were selected for their sorption or ion exchange characteristics [K.LG, kraft lignin; P.SP, commercial fibric peat *(Sphagnum);* P.SA, sapric peat from the Torreblanca deposit, Spain; C.AC, vegetable charcoal; G.MI, gypsum; P.MI, $Ca(PO_4H_2)_2{\cdot}2H_2O$].

Special attention was paid to the examination of different additional N forms in the straw, including ammonia (N.NS), mineral salts [C.NS: $Ca(NO_3)_2$], urea (U.NS), amino acids (A.NS, Difco casamino acids), and other N-rich subproducts (B:NS, dry blood; F.NS, fish meal).

To study the effect of removing preexistent phytotoxic compounds, a sample labeled W.EX was prepared from straw subjected to previous extraction of the water-soluble fraction. The additives were used in doses of 10% (dry wt basis) (R.BE, P.BE, F.NS, W.DR, G.HK, and K.LG.), 5% (P.SP and C.AC), or 1%: (B.BE, Y.BE, A.NS, B.EZ, B.NS, T.LB, V.SH, and P.SA). Except in N.NS, U.NS, and C.NS, the C/N ratio of the mixtures was adjusted to 20 with NH_4NO_3, taking into account the percentages of C and N of the different substrates.

Compost samples were desiccated at 60 °C and ground to 200 μm in a knife mill at intervals followed by sieving. The DTG curves were repeated after the most soluble compost fraction was removed by suspending 1 g of compost in 30 mL of water, which for a day was occasionally shaken at room temperature. After centrifuging, the compost residue was recovered, dried, and sieved to 200 μm. Samples of 10 mg of compost were analyzed in a Perkin-Elmer TGS-2 thermobalance, operating a heating rate of 20 °C min^{-1} in an air atmosphere. The original plots corresponding to thermogravimetric curves were transferred to a personal computer through a hand scanner in the 400 dpi resolution mode. By using the authors' computer programs, the raster files with the cumulative curves (40−580 °C range) were vectorialized, adjusted to 640 data points, and subjected to further digital treatments including derivation, smoothing, peak detection, and supervised area measurements.

The elemental composition (C%, H%, N%) of the compost samples was determined with a Carlo Erba CHNS-O-EA1108 microanalyzer. The O% was obtained by the difference with ash-free percentages, and the atomic H/C and O/C ratios (Van Krevelen, 1950) were calculated.

The pH was measured with a glass−calomel electrode in 1:10 (w/v) water suspensions. The major organic fractions of the compost were determined gravimetrically after sequential removal. The lipid fraction was removed with benzene−ethanol in a Soxhlet extractor, which was used for further extraction of the water-soluble products (TAPPI, 1975). Klason lignin was determined in the extraction residue (TAPPI, 1974).

A germination test using seeds of garden cress *(Lepidium sativum)* was carried out following the method of Hirai et al. (1983). Replicate 9-cm Petri dishes with 10 seeds on a filter paper and 8 mL of extract (5 g of dry compost + 50 mL of H_2O were incubated at 27 °C for 2 days. The phytotoxic substances were detected for their inhibiting effect on germination and referred to as "germination indices" by multiplying the mean root length by the percentage of viable seeds.

A total of 40 parameters were determined in the compost samples (Blanco et al., 1992), the present study mainly referring to those showing some connection with the results of the thermogravimetric analyses.

For the greenhouse experiment, ryegrass *(Lolium rigidum)* was sown in 2-kg pots (2 g of seed) containing soil samples from the CSIC experimental farm "La Higueruela", a representative example of the dryland agrosystems of central Spain. The soil samples were taken from different plots of a Calcic Haploxeralf, where microtopographic features led to a mosaic-like distribution of carbonates. To study the effect of carbonates on the compost performance in the soil, two different plots were sampled. The topsoil (0−20 cm) of plot A had organic C 0.5%, CO_3^{2-} <1%, pH 7.4, CEC 12.5 $cmol_c\ kg^{-1}$, sand 78%, silt 8%, and clay 14%. Plot C had organic C 1.0%, CO_3^{2-} 7.9%, pH 8.2, CEC 23 $cmol_c\ kg^{-1}$, sand 53%, silt 25%, and clay 22%.

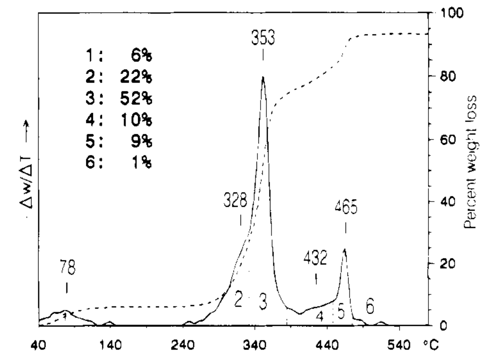

Figure 1. Thermogravimetric curve (dashed line, right *Y* axis) and DTG curve (solid line) of wheat straw after water extraction.

A total of 12 of the above 22 samples were used in this greenhouse experiment. Two replications were made, and the compost application rate was 1% (w/w). To prevent nutrient deficiencies in the course of the experiment, Hoagland's solution was periodically applied to the pots.

To examine the different stages of plant growth in the course of the greenhouse experiment, the ryegrass was harvested every 2 weeks by cutting off plants at a height of 2.5 cm. A total of four harvests were obtained, the oven-dried plant biomass was weighed, and the final values were presented as percentage increases compared with the corresponding controls (soil samples A and C with no organic matter added).

RESULTS AND DISCUSSION

Thermogravimetric Study. Figures 1 and 2 show typical DTG curves obtained from wheat straw and composts after extraction with water. In general, the curves showed a prominent effect at 320−360 °C with a maximum around 340 °C representing ca. 40% of the total weight loss (LW3b, Table 2) and preceded by an ill-resolved peak (LW3a). Both effects represented around 65% of the total weight loss (LW3, Table 2) and are interpreted as being due to compost decarboxylation, in addition to the dehydration and oxidation of carbohydrate and of the less condensed structures of the lignin macromolecules. At a comparatively higher temperature (variable maximum around 440 °C) the moderate weight losses are attributed to the destruction of the most resistant plant polymer moieties, such as condensed lignins and humic-like colloids formed in the course of composting or melanoidins formed in the previous thermal decomposition stages. Three successive effects were considered in terms of the most frequent valleys in the high-temperature region of the DTG curve. It is noted that the areas for the different regions in Table 2 were obtained from a supervised division suggested by the valleys found in every case, which are not exactly the same when the different samples are compared (Figures 1 and 2). The low-temperature effect (ca. 70 °C, representing around 6% of the total weight loss) is traditionally considered to be due to dehydration.

The above patterns were comparable to that of wheat straw, the main differences consisting of the comparatively greater intensity of the effects at 340 °C and the practical absence of an effect at the highest temperature (ca. 470 °C, Figure 1).

Of the first set of curves obtained from the nonextracted compost samples, considerably erratic values were found in terms of the patterns observed for the other variables examined (Tables 1 and 2). These DTG data showed no highly significant correlation with other compost parameters.

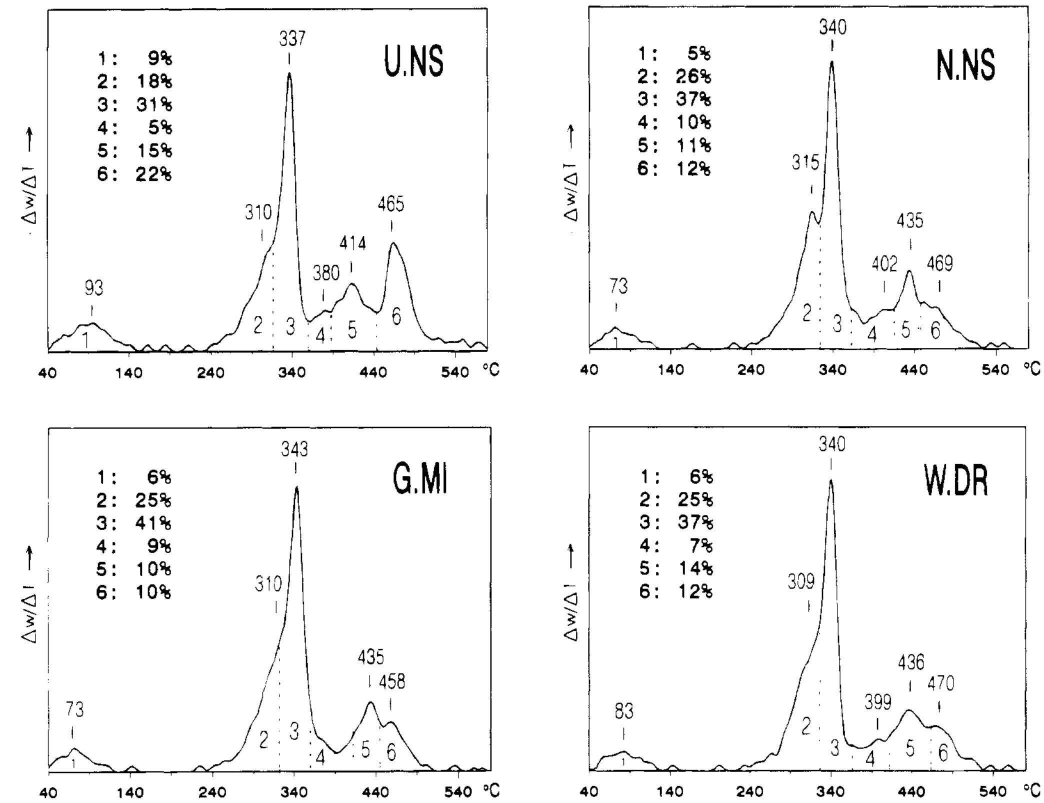

Figure 2. Peak area quantifications in DTG curves of wheat straw composted with different additives and/or nitrogen sources (U.NS, urea; N.NS, ammonia; G.MI, gypsum–NH_4NO_3; W.DR, wine drawn–NH_4NO_3).

Table 1. Some Analytical Characteristics of Wheat Straw and Wheat Straw Composts[a] Prepared with Different Organic and Mineral Additives

				atomic ratios		phytotoxicity measurements[b]			compost fractions[c] (wt %)			
	pH	C%	C/N	H/C	O/C	G%	L	Gi	LIP	WSE	LIG	ash
straw	5.7	47.0	75.8	1.53	0.68	0	0	0	8.2	13.8	18.1	4.0
W.EX	5.1	42.8	17.7	1.25	0.55	13	15	3	5.5	8.7	31.1	2.9
U.NS	6.7	43.2	14.4	1.23	0.45	91	76	94	3.5	16.3	49.6	10.3
C.NS	6.9	37.8	14.3	1.31	0.61	52	25	17	6.3	22.0	29.3	9.2
G.MI	6.1	40.5	12.8	1.29	0.55	52	30	26	5.5	13.7	37.1	6.8
P.MI	6.7	41.5	13.3	1.26	0.53	52	35	1	4.8	15.1	34.0	6.4
N.NS	6.8	45.0	31.9	1.22	0.47	52	71	40	3.5	11.6	33.3	7.3
B.BE	7.0	40.8	15.2	1.28	0.56	65	35	18	5.2	12.1	31.5	6.3
Y.BE	6.4	42.3	14.6	1.25	0.52	104	40	47	6.5	12.8	33.1	6.3
R.BE	6.2	40.1	10.6	1.26	0.52	0	0	0	2.1	21.3	42.8	6.5
P.BE	6.0	41.5	11.9	1.23	0.54	65	40	30	4.9	10.5	32.2	5.7
A.NS	6.1	43.2	14.3	1.27	0.50	13	5	1	4.6	17.0	33.5	5.9
B.EZ	5.9	42.6	12.5	1.30	0.51	0	0	0	2.5	17.1	18.1	5.6
B.NS	6.2	42.4	14.4	1.29	0.51	52	30	24	4.5	13.5	30.3	6.0
C.TL	6.1	41.8	14.5	1.25	0.33	0	0	0	5.4	11.7	33.1	6.0
F.NS	6.9	41.5	12.3	1.25	0.49	91	76	104	2.6	15.1	43.6	9.4
V.DR	6.3	41.4	18.0	1.21	0.53	117	131	207	4.5	13.5	37.4	8.5
G.HK	5.6	42.7	15.6	1.26	0.51	39	30	16	25.5	5.4	35.0	6.0
V.SH	5.8	41.7	14.4	1.30	0.53	26	10	2	7.1	13.9	33.5	6.4
L.LG	5.5	43.8	14.3	1.18	0.48	52	35	19	11.4	14.9	40.7	6.5
P.SP	6.1	38.2	14.3	1.25	0.58	0	0	0	6.5	11.1	34.3	6.0
P.SA	6.3	41.7	14.0	1.31	0.53	65	25	20	5.7	13.8	37.3	6.0
C.AC	5.9	43.6	14.3	1.26	0.47	65	71	62	6.2	12.8	39.6	7.0

[a] Sample labels refer to additives or pretreatments: W.EX, straw composted after water pretreatment; U.NS, urea; C.NS, $Ca(NO_3)_2$; G.MI, gypsum; P.MI, $Ca(PO_4H_2)_2{\cdot}2H_2O$; N.NS, ammonia; B.BE, bagasse; Y.BE, yeast; R.BE, rootlets; P.BE, powder; A.NS, amino acids; B.EZ, Bio-Enz (commercial priming); B.NS, dry blood; C.TL, *Trichoderma* cellulase; F.NS, fish meal; W.DR, wine drawn; G.HK, grape husk; V.SH, vine shoot; K.LG, kraft lignin; P.SP, *Sphagnum* peat; P.SA, sapric peat; C.AC, vegetable charcoal. [b] G% = percent germination, L = average root length; Gi = germination index (percentages compared with the control in distilled water). [c] Difference with regards to 100 = holocellulose. LIP, ethanol–benzene extract; WSE, water-soluble; LIG, Klason lignin.

Figure 3 illustrates the shape of an DTG curve prior to and after water extraction from the composts. The DTG curves from the original composts showed comparatively sharp peaks, which appeared at lower temperatures. These curves appeared to have a higher resolution than those of the water-extracted samples: there was an effect between 175 and 290 °C relatively independent of the major maximum at ca. 305 °C, and the peak in the high-temperature region (400–490 °C) was unique and sharp. The comparison of the curves prior to and after water extraction suggested a comparatively rapid and intense decomposition in the

Table 2. Peak Area Quantification of Wheat Straw and Wheat Straw Composts[a] in Differential Thermogravimetric Curves

	original samples[b]					water-extracted samples[c]							
	E0	E1	E2	E3	E4	LW0	LW3a	LW3b	LW4a	LW4b	LW4c	LW3	LW4
straw	3	22	65	7	3	5.7	22.4	52.3	10.1	9.3	1.1	74	20
W.EX	4	18	44	22	12	4.5	24.2	45.7	5.2	6.9	12.9	70	25
U.NS	8	7	39	8	38	8.9	18.1	31.2	4.7	15.0	22.4	49	42
C.NS	9	14	39	11	27	5.9	19.9	49.3	10.8	12.1	2.1	69	25
G.MI	5	22	39	18	16	6.3	24.5	41.2	8.5	10.4	9.6	66	28
P.MI	3	21	40	15	21	5.8	24.2	40.0	9.2	6.9	14.2	64	30
N.NS	6	16	47	21	10	5.3	25.5	37.3	10.1	11.0	11.6	62	33
B.BE	5	20	40	11	24	4.7	24.7	41.0	9.8	8.3	10.7	66	29
Y.BE	4	18	43	14	21	5.7	25.5	43.5	8.9	6.4	10.1	69	25
R.BE	5	23	38	16	18	3.5	27.1	45.4	6.5	5.5	11.7	72	24
P.BE	5	22	39	14	20	5.2	26.0	39.1	9.7	11.9	9.1	65	30
A.NS	5	22	54	4	15	5.2	19.1	46.1	7.1	14.4	8.2	65	30
B.EZ	5	20	38	18	19	5.0	25.8	41.5	8.0	14.0	6.6	67	28
B.NS	5	21	40	14	20	6.4	27.8	39.2	9.6	10.7	8.3	66	28
C.TL	3	22	40	14	21	6.1	23.6	41.6	17.1	9.0	2.7	65	29
F.NS	4	17	34	13	32	6.8	21.7	33.5	6.0	15.1	17.9	54	39
V.DR	4	19	44	9	24	7.3	25.0	37.0	7.0	13.8	11.9	61	32
G.HK	4	20	35	21	20	6.1	24.2	36.4	9.5	14.6	9.7	60	34
V.SH	3	24	41	9	23	4.8	22.5	43.9	7.3	11.4	9.7	66	29
L.LG	3	19	41	24	13	5.1	20.6	38.5	9.8	6.5	19.7	59	36
P.SP	3	21	41	19	16	6.5	22.4	44.4	8.0	14.3	5.3	66	27
P.SA	3	18	39	25	15	2.9	24.5	38.4	12.4	11.6	10.1	63	34
C.AC	5	18	39	21	17	6.1	24.1	38.3	8.6	7.4	16.4	62	32

[a] Sample labels same as in Table 1. [b] E0, weight loss in the interval between 50 and 115 °C; E1, 175–290 °C; E2, 290–320 °C; E3, 320–400 °C; E4, 400–490 °C. [c] LW0, weight loss in the interval between 50 and 120 °C; LW3a, 250–320 °C; LW3b, 320–360 °C; LW3, LW3a & LW3b; LW4a, 360–420 °C; LW4b, 420–450 °C; LW4c, 450–540 °C; LW4, LW4a & LW4b & LW4c.

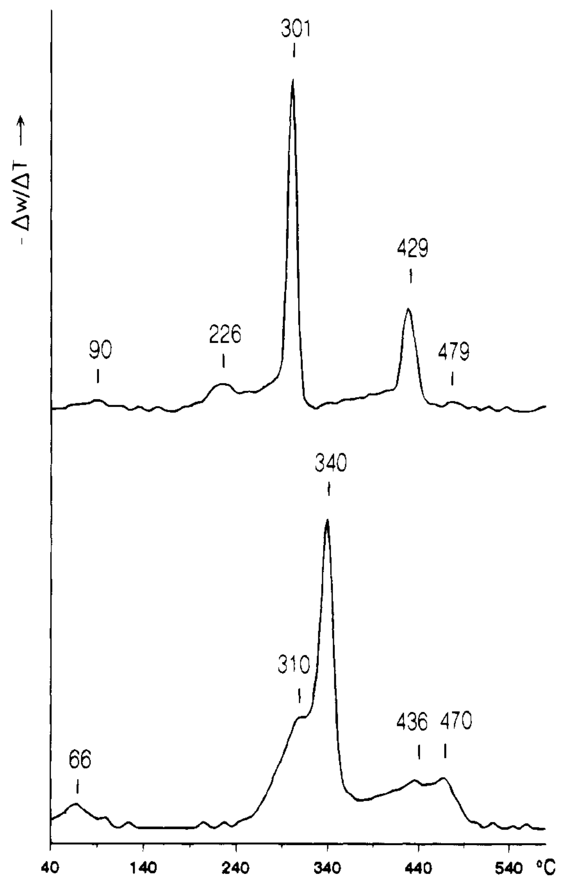

Figure 3. (Top) DTG curves of wheat straw composted after the addition of barley bagasse (sample B.BE); (bottom) the same after extraction of the water-soluble fraction.

former case. This circumstance may in part be due to the water-soluble mineral constituents of the compost. The effect of salicification in the shifting of the exothermal peaks toward lower temperatures has been shown in humic substances (Hoffmann and Schnitzer, 1965; Lévesque and Schnitzer, 1967) and peats (Almendros et al., 1982). In fact, considerable changes were found in the DTG pattern of wheat straw after the addition of ammonium carbonate in low amounts similar to those used in the present experiment to adjust the substrate C/N ratio to 20. The addition of other salts (sodium bicarbonate, calcium carbonate, potassium carbonate, etc.) also led to qualitative and quantitative changes in the DTG curves. It is postulated that the conspicuous effect of some salts during the thermal analysis of composts should in part be compared to base-catalyzed dehydration, thus enhancing the continuous disruption of bonds between polymer structures which should otherwise occur at a greater temperature. In addition, the oxidizing or fire-retardant effect of residual inorganic anions should not be avoided. A classical systematic study on the effects of salt additives on the DTG patterns of forest products was presented in Tang (1972).

Table 3. Significant (P < 0.05%) Linear Correlation Indices[a] between Peak Area Values from DTG Curves and Some Compost Maturity Parameters

	thermal effect[b]			
	LW3	LW4	LW3b	LW4c
pH	−0.4350*	0.4701*	−0.5325**	ns
C/N ratio	ns	−0.3812*	0.4382*	ns
atomic H/C	0.5327**	−0.5623**	0.6207**	−0.5810**
atomic O/C	0.5188**	−0.5463**	0.5812**	ns
% germination[c]	−0.5605**	0.5342**	−0.6185**	0.5386**
av root length[c]	−0.6326**	0.5899**	−0.6765**	0.5765**
germination index[c]	−0.5517**	0.4864*	−0.5601**	0.4386*
lignin (wt %)	−0.6899**	0.6925**	−0.6359**	0.7615**

[a] *, P < 0.05; **, P < 0.01; ns, P > 0.05. [b] LW3, weight loss in the interval between 250 and 360 °C; LW4, 360–540 °C; LW3a, 250–320 °C; LW3b, 320–360 °C; LW4c, 450–540 °C. [c] Phytotoxicity test with *Lepidium sativum* seeds.

From the above results, the subsequent study was carried out by exclusively using the samples subjected to water extraction.

DTG Curves and Compost Parameters. As expected, the area of the high-temperature effects (LW4) correlated (P < 0.01) with the lignin content (Table 3).

Table 4. Plant Yield[a] of Soils[b] Amended with Wheat Straw and Wheat Straw Composts[c]

	soil A					soil C				
	I	II	III	IV	total	I	II	III	IV	total
straw	−79	−100	−96	−100	−94	34	−84	−97	−100	−55
W.EX	48	−28	−23	52	4	37	−43	−62	−37	−25
C.NS	76	17	9	43	32	34	−30	−31	−12	−9
G.MI	48	−14	−21	10	1	21	11	−21	−12	2
P.MI	9	10	−5	24	6	42	14	0	0	16
N.NS	70	76	18	71	50	42	43	10	75	37
A.NS	91	76	71	129	86	68	11	−3	19	25
B.EZ	58	31	−11	81	28	37	41	−18	−37	12
B.NS	42	21	43	114	49	18	−27	−5	81	6
C.TL	55	14	5	10	19	18	−16	21	38	12
P.SP	55	114	32	67	60	24	30	18	50	27
C.AC	61	14	2	−14	16	34	8	10	6	16

[a] Percentages in comparison to plant yield in the corresponding control soils (no organic matter added). [b] Soil A, Calcic Haploxeralf (% CO_3^{2-} < 1). Soil C, Calcic Haploxeralf (% CO_3^{2-} = 7.9). I−IV correspond to successive harvests at 2-week intervals. [c] Sample labels same as in Table 1.

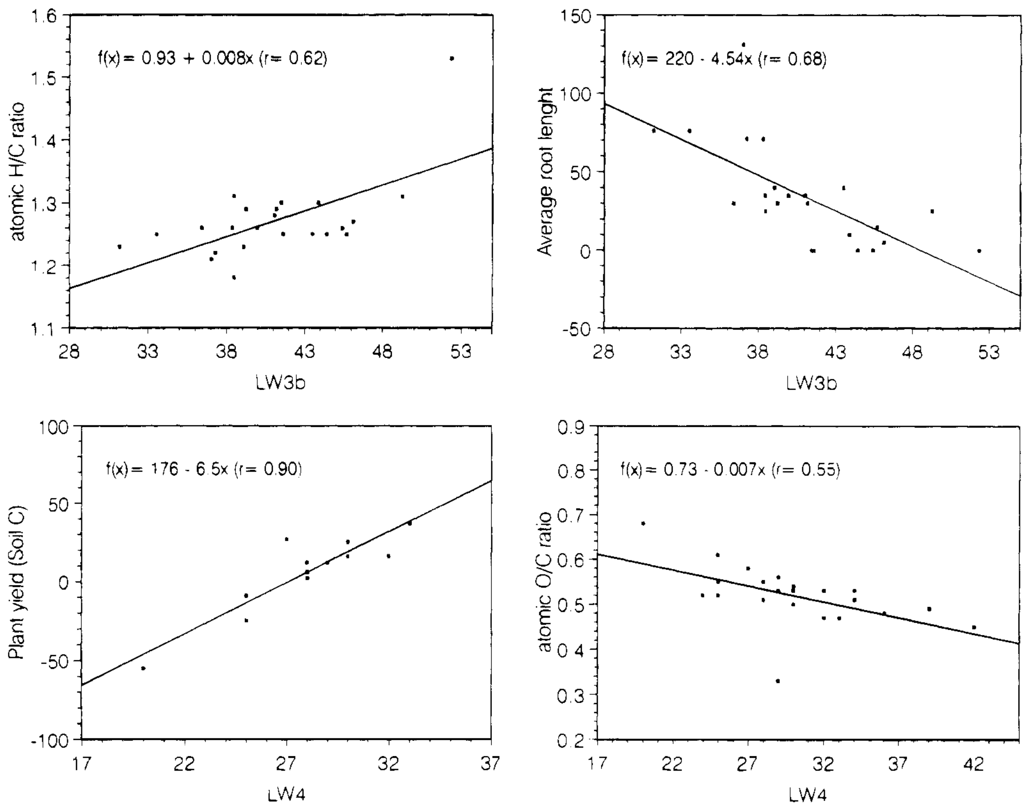

Figure 4. Linear correlations between DTG areas and some chemical compost properties, or plant yield of soils amended with 1% compost. LW3b, weight loss between 320 and 360 °C; LW4, weight loss between 360 and 540 °C.

In particular, LW4 correlated negatively with the atomic H/C ratio as well as with the O/C ratio, suggesting increased thermal stability after selective depletion of the constituents with a pronounced aliphatic character and a high proportion of O-containing groups, such as carbohydrate. In addition, LW4 also showed a significant negative correlation with the C/N ratio. It is considered that the above set of parameters in mutual correlation represents the most conspicuous chemical maturity indicators for the compost of the present study.

The LW4 area was found in connection with the results of the phytotoxicity tests. This area value correlated significantly with the average root length and, to a lesser extent, with the percentage of germinated seeds.

The results of the greenhouse experiment are shown in Table 4, where negative values (percentage increases with respect to the control soils) indicate the depressive effect of wheat straw and the less mature composts on plant yield. It was found that plant production in soils amended with composts paralleled the LW4 area (Table 5). This was true for the soil samples with the greatest carbonate content (plot C) as well as for the neutral ones (plot A), the correlation being more significant in the former case. When the results of the total final production are compared with those obtained in the intermediate stages (harvests I−IV), it is found that in various cases the highest correlations corresponded to stage II (2−4 weeks). This may suggest that the greatest activity occurs in this growth stage due to the transformation of nonmatured composts into soil.

The information provided by the thermal effects was also studied after the above-mentioned curve areas were subdivided into narrower regions corresponding to the different individual peaks (Table 2). The main effect (LW3) was considered to consist of two independent, ill-resolved LW3a and LW3b stages (2 and 3, Figures 1 and 2), the curve division being decided in each case

Table 5. Significant ($P < 0.05$) Linear Correlation Indices[a] between Peak Areas[b] in the DTG Curves and Plant Yield of Soils[c] Amended with Wheat Straw or Composted Straw

	LW3	LW4	LW3b	LW4b
soil A, harvest I	−0.6251*	0.6571*	ns	ns
soil A, harvest II	−0.6708*	0.6469*	ns	0.6112*
soil A, harvest III	−0.6496*	0.6450*	ns	ns
soil A, harvest IV	ns	ns	ns	ns
soil A, total harvest	−0.6505*	0.6608*	ns	ns
soil C, harvest I	ns	ns	ns	ns
soil C, harvest II	−0.7874**	0.7913**	−0.6816*	ns
soil C, harvest III	−0.9030**	0.8466**	−0.7331**	ns
soil C, harvest IV	−0.7422**	0.7002*	−0.6641*	ns
soil C, total harvest	−0.9136**	0.8981**	−0.7281**	ns

[a] *, $P < 0.05$; **, $P < 0.01$; ns, $P > 0.05$. [b] LW3, weight loss in the interval between 250 and 360 °C; LW4, 360−540 °C; LW3b, 320−360 °C; LW4b, 450−540 °C. [c] Soil A, Calcic Haploxeralf (% CO_3^{2-} < 1). Soil C, Calcic Haploxeralf (% CO_3^{2-} = 7.9). I−IV correspond to successive harvests at 2-week intervals.

after additional examination of the first derivative of the DTG curve. In the same way, the high-temperature zone (LW4) was divided into intervals from LW4a to LW4c (4−6, Figures 1 and 2).

After this new division of the DTG curve, it was observed that some curve regions appeared to be meaningless in terms of the maturity indices, whereas for other regions improved correlations were obtained (Table 3; Figure 4). In particular, no significant correlation with other compost parameters was achieved for the LW3a region—probably due to carbohydrate dehydration—as opposed to LW3b, which was found to be the most interesting in terms of most compost parameters (Table 3). This does not occur with regard to plant yield, where the use of the peak area values for the complete curve intervals (LW3 or LW4) was required to obtain the best correlations (Table 5). In general, no special improvement was obtained when high-temperature peak LW4 was subdivided. No substantial number of significant correlations was found for the isolated LW4a and LW4b regions, but it was found that the extent of the greatest temperature peak, i.e., LW4c, best reflected the amount of lignin in the composts.

Finally, and assuming that the DTG data are valid to assess the transformation achieved by the different compost samples studied, Table 2 suggests the favorable effect of composting with urea as nitrogen source. This also occurs with protein-rich additives such as fish meal. However, the less expensive pretreatment of ammonifying straw also led to intense compost transformation. The improving effect of the addition of some stable colloidal additives was observed with industrial lignin or sapric peat. On the other hand, some wastes from beer industries (R.BE, Y.BE) were not suitable primings for straw composting. The straw from which the water-soluble fraction was removed does not lead to valuable compost. The same occurs in that composted with $Ca(NO_3)_2$ as a sole source of N.

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