Compost properties related to particle size

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Abstract

Several properties (pH, electrical conductivity, contents of organic matter, nutrients, heavy metals, glass and impurities) were determined in different particle size fractions (0-0.5, 0.5-2, 2-5, 5-10, 10-25 and >25 mm) of various MSW composts produced in two composting facilities located at SW Spain (Montemarta-Sevilla and Villarrasa-Huelva). Mean percentages of the first five fractions were 9.6, 22.7, 29.2, 23.4 and 15.1 respectively.The MSW compost properties depended on particle size. Fine fractions (<2 mm) shown better quality than the mean compost: lower EC, Na content, C/N ratio, less glass and impurities indicated higher maturity and cleanness. Though this fine fraction had lower nutrient contents and the 0.5-2 mm fraction accumulated heavy metals, separation of the fine fraction would produce a compost more suitable for applications which require high stability compost, such as component for pot substrates. On the other hand, the >2 mm fractions tended to be richer in fertilizing elements, probably in relation with OM mineralization.

Introduction

Composting has been adopted in Spain as the main alternative for municipal solid waste (MSW) treatment, being soil improvement and fertilization the main uses for these composts. The beneficial effects of composts on crop production and soil properties are directly related to the physical, chemical and biological properties of the composts. New markets and uses are needed to absorb the increasing amounts of MSW compost but at the same time, stricter regulations appear to fulfil quality requirements for new uses and to guarantee environmental protection [1].

The knowledge of properties depending on particle size would help to the production of tailor-made composts obtained easily by sieving and also to the observance of future regulations.

This paper studies the dependence of nutrient contents (organic matter, N, P, K, Ca, Mg) and contaminants (glass, impurities, salinity, heavy metal contents) on the particle size of MSW composts.

Materials and Methods

Facility information

Composts samples were collected from two composting facilities in SW Spain: Montemarta-Sevilla (3 samples), which process more than 10^6 kg of MSW day^{-1} and produces 108 · 10^6 kg of compost year^{-1}, and Villarrasa-Huelva (7 samples), which process 5 · 10^5 kg day^{-1} and produces 35 · 10^6 kg of compost year^{-1}. The feed stock at both facilities consists of unsorted MSW (in Andalusia only glass and paper are separately collected). Additional glass, paper, some plastics and ferric metals are separated in the facilities. MSW is then mixed and sieved (<80 mm), and undergoes composting in windrows for 7 weeks, with turning once a week. Final screening reduces the particle size to <25, <15 or <12 mm. Compost is left to mature a minimum of 3 months. Madrid *et al.* [2] described additional details about the characteristics of the MSW, composting and compost properties.

Sampling

During 2001 a total of 10 composite samples (5-15 kg) were collected in both facilities. These samples differed not only in their origin but in their maximum particle size (3 samples <80 mm, 1 sample <25 mm, 4 samples <15 mm, 1 sample < 12 mm) and their degree of maturity (ranging from fresh MSW feed stock to one year mature compost.

Particle size fractionation of compost

Composts samples were oven dried (70°C, forced aeration) during 72 hours and fractionated in a sieve tower. Sieves of 25, 10, 5, 2 and 0.5 mm were utilized. The 25 mm sieve was selected because this is the maximum particle size permitted by Spanish regulations [3]. Medium sieves (10, 5 and 2 mm) were selected to obtain similar amounts on each sieve. The 0.5 mm sieve was included to separate small particles. The aggregates in the sieves were broken by a pestle. Each fraction was weighted and expressed as percentage of the sample weight. Glass and other impurities (stones, metals, plastics) were removed, weighted and expressed as percentage of the fraction weight. The aspect of the fractions at this moment was homogeneous.

Chemical analysis of fractions

All fraction samples were ground to <0.5 mm using a cutting mill. Electrical Conductivity (EC) and pH were determined in a 1:5 (w/vol.) compost-water slurry. Due to drying it was necessary to leave the samples several hours in water to permit rewetting. Organic matter (OM) was determined from the loss on ignition at 550°C. Organic-C was estimated as OM/2. Kjeldahl-N was determined by titration after H_2SO_4-KCl-Se digestion at 420°C. Total elemental composition (excluding N and C) was performed by ICP-OES after aqua-regia digestion on microwave oven.

Control samples from the MARSEP-WEPAL [4] program were run with each set of samples. Comparison of the measured and expected mean values generally yielded recoveries between 95 and 105%, but a few elements shown recoveries between 90-110%.

Statistical analysis

Data analysis was conducted performing analysis of variance. Mean separations were determined by the Tuckey test ($p<0.05$) using SPSS.

Results and Discussion

Particle size distribution

Figure 1 shows the mean particle size distribution. Fraction >25 mm, which was only present in the 3 MSW <80 mm feed stock samples, was excluded in the figure and the percentage of the other fractions in these samples was adjusted to amount to 100. The average percentage for the >25 mm fraction in these samples was 30.2% which can be considered to be the minimum loss of the final refining process (maximum compost particle size in Spain is 25 mm [3]). The percentage of the other fractions was of the same order of magnitude, being lower for the 0-0.5 and 10-25 mm fractions. The mean percentage for the 10-25 mm fraction is biased due to the final screening (<12 or <15 mm) of several compost samples.

Compost characteristics

Table 1 summarizes the characteristics of mean fractions of composts and of the "mean" compost. To calculate the characteristics of the "mean" compost, weighted means of each parameter were determined using individual values in each fraction and the percentages of the fractions as weighting factors. The values in the table are the mean of these weighted means.

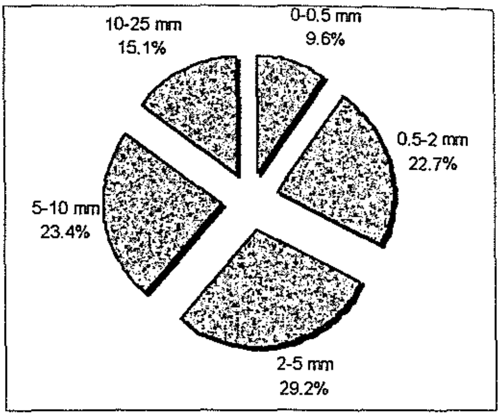

Figure 1: Particle size distribution

In general, the "mean" compost properties were similar to the values given by Madrid *et al.* [2] and López *et al.* [5] who studied in more detail the properties of composts varying in maximum particle size from the same facilities. The most outstanding characteristics were:

a) the high content of glass and other impurities and the high level of salinity (EC), that prevented the use of these composts as potting substrates;

b) the pH, that could indicated lack of maturity; though some samples were not finished compost, pH was below 6.3 except for one sample;

c) the high C/N ratio, indicative of lack of maturity and that could produce N-immobilization [6];

d) the content of heavy metals that exceeded possible future limits fixed by the European Commission [1]; the mean contents of Cr, Cu, Ni, Pb and Zn were 1.52 to 2.43 times the limits for compost without restriction in use.

Fraction characteristics

In general, the fraction mean values fluctuated between ± 1.5 times the corresponding value for the "mean" compost (table 1). The exceptions were pH, that presented similar mean values in all the fractions, and some heavy metal contents in certain fractions, that shown greater variability.

The selected compost samples were very different. To overcome the difficulty of comparing the fractions from this various set of samples, the studied parameters were normalized, dividing the fraction result by the corresponding value for each "mean" sample, and expressing the result as percentage. Tables 2, 3 and 4 show the mean of the normalized parameters for each fraction.

Table 2 shows some detrimental properties to the compost quality. Glass and impurities contents, EC, Na content and C/N ratio were lower in the <2 mm fractions and greater in the three fractions of particle size between 2 and 25 mm. Glass and impurities contents were null below 2 mm, though in these fractions the null means not detected (table 1) or impossible to hand separate. EC and Na content increased as particle size increased, except for the coarse fraction >25 mm (this fraction only was present in 3 samples). C/N ratio and OM (table 1) also increased as particle size increased. Mean C/N ratio for

Table 1. Properties of the mean fractions of composts and of "mean" compost (mean of weighted means) (n.d., not detected).

		<0.5 mm	0.5-2 mm	2-5 mm	5-10 mm	10-25 mm	>25 mm	Mean compost
Glass	%	n.d.	n.d.	12.7	28.0	25.0	4.7	13.3
Impurities	%	n.d.	n.d.	1.0	11.7	21.7	27.1	7.4
pH		6.21	6.39	6.15	6.15	6.34	6.03	6.25
EC	dS m^{-1}	6.49	8.15	11.1	10.3	11.6	11.1	9.91
OM	%	29.2	44.8	56.0	62.7	64.3	65.8	56.0
C/N ratio		16.6	20.3	22.7	27.0	28.8	32.7	26.0
Kjeldahl-N	%	0.90	1.13	1.25	1.24	1.16	1.42	1.16
P (as P_2O_5)	%	0.730	0.820	0.964	0.823	0.644	0.441	0.776
K (as K_2O)	%	0.466	0.681	0.883	0.867	0.976	0.522	0.754
Ca	%	3.65	5.34	5.97	5.44	4.44	3.66	5.22
Mg	%	0.311	0.427	0.505	0.380	0.320	0.326	0.416
Na	%	0.386	0.576	0.731	0.768	0.746	0.463	0.655
S	%	0.460	0.514	0.609	0.523	0.490	0.377	0.508
Fe	%	0.918	1.114	0.932	0.832	0.667	0.321	0.899
Al	%	0.505	0.457	0.458	0.404	0.377	0.160	0.432
As	mg kg^{-1}	7.46	6.09	7.82	5.68	5.15	2.74	6.45
B	mg kg^{-1}	20.0	26.8	30.1	26.2	24.6	7.34	23.8
Cd	mg kg^{-1}	0.370	0.350	0.354	0.396	0.235	0.180	0.343
Co	mg kg^{-1}	3.18	5.14	4.03	3.70	3.72	2.16	4.00
Cr	mg kg^{-1}	63.1	313	201	186	136	64.7	190
Cu	mg kg^{-1}	212	359	227	204	162	48.6	228
Mn	mg kg^{-1}	178	213	207	178	137	86.6	185
Ni	mg kg^{-1}	29.5	131	83.8	74.2	57.2	29.8	79.2
Pb	mg kg^{-1}	291	295	245	184	140	85.2	243
Sn	mg kg^{-1}	83.6	74.1	82.7	16.0	16.6	5.66	50.3
Zn	mg kg^{-1}	290	337	295	310	349	93.0	304

0-0.5mm fraction was 16.6 (table 1) or 64% (table 2), a value more indicative of maturity, while C/N=32.7 (110%) for the >25 mm fraction. Mean C/N ratio and OM for the fractions seems correlated, being similar their percentages (table 2). Körner *et al.* [7] also described an increasing (polynomial) tendency between C/N ratio and particle size, indicating C/N ratios between 8 and 35 for fresh biowaste compost. The same authors observed a significant correlation between OM and particle size, being the maximum twice the minimum within the fractions of one sample, approximately, the same difference observed in this study (53 to 114% OM, table 2). The tendencies of OM and C/N ratio have to be related to the increase of specific surface as the particle size diminishes, facilitating the degradation (active composting) of the organic substances.

Table 3 shows the distribution of nutrients in the fractions. Kjeldahl-N content was lower in the 0-0.5 mm fraction, but the difference was not significant. Körner *et al.* [7] found a slightly significant downward trend with increasing particle size, but also found and upward trend of Kjeldahl-N on OM. In this case, both tendencies could have been compensated. The other nutrients, P, K, Ca, Mg and S shown the same tendency: their contents were lower in the 0-0.5 mm fraction and in the 10-25 (except for K) and in the >25 mm fractions. In addition to differences in the materials that compose each fraction, the lower mineralization (high OM content) in the coarse fractions could lead to the dilution of nutrients. For the 0-0.5 mm fraction, the lower nutrient contents were probably due to the different nature of the material that compose the particles. In fact, the heavy metal contents (table 4) followed the same pattern described for the nutrients, except for higher Fe, what could indicated the presence of soil particles, whose heavy metal contents (except Fe) were usually lower. The percentages of Cr (33%) and Ni (38%) in the 0-0.5 mm fraction were very reduced. The Cd and Pb contents shown no clear differences between the fractions.

On the contrary, fractions between 0.5 and 10 mm had higher nutrients and heavy metal contents (percentages greater than 100, tables 3 and 4). In general, the 2-5 mm fraction was the most concentrated in nutrients, except for K (table 3), reaching percentages of 110 to 127%. Rieβ (cited by Körner *et al.* [7]) indicated that the fine fraction (<10 mm) may show high nutrient contents, which correspond to the present results. The fraction richer in heavy metals was the 0.5-2 mm (table 3), decreasing the percentages as the size particle increased, probably in relation with OM mineralization.

Table 2. Some properties of compost fractions expressed as percentage of the sample weighted average (values followed by the same letter in the same column do not differ significantly, Tuckey test, $p<0.05$).

	Glass	Impurities	EC	Na	C/N ratio	OM
0-0.5 mm	0 a	0 a	68 a	58 a	64 a	53 a
0.5-2 mm	0 a	0 a	81 ab	88 bc	81 ab	81 b
2-5 mm	97 b	7 a	112 bc	112 cd	88 ab	100 bc
5-10 mm	208 c	248 ab	104 bc	118 d	108 ab	114 c
10-25mm	189 c	463 ab	119 c	117 d	111 b	114 c
>25 mm	33 ab	297 ab	93 abc	76 ab	110 ab	99 bc

Table 3. Nutrient contents of compost fractions expressed as percentage of the sample weighted average (values followed by the same letter in the same column do not differ significantly, Tuckey test, $p<0.05$).

	N	P_2O_5	K_2O	Ca	Mg	S
0-0.5 mm	81 a	93 ab	63 a	71 a	77 a	91 ab
0.5-2 mm	100 a	108 ab	91 ab	107 b	107 ab	103 ab
2-5 mm	110 a	127 b	115 bc	117 b	120 b	121 b
5-10 mm	109 a	113 ab	114 bc	103 b	95 ab	103 ab
10-25mm	98 a	85 ab	125 c	88 ab	81 a	93 ab
>25 mm	96 a	74 a	61 a	94 ab	96 ab	80 a

Table 4. Heavy metal contents of compost fractions expressed as percentage of the sample weighted average (values followed by the same letter in the same column do not differ significantly, Tuckey test, $p<0.05$).

	Cd	Co	Cr	Cu	Fe	Ni	Mn	Pb	Zn
0-0.5 mm	83 a	87 a	33 a	102 ab	120 ab	38 a	101 abc	118 a	100 ab
0.5-2 mm	143 a	130 b	171 b	168 b	134 b	173 b	120 c	119 a	116 b
2-5 mm	94 a	104 a	122 ab	99 ab	110 ab	121 ab	115 bc	98 a	100 ab
5-10 mm	133 a	94 a	104 ab	92 ab	93 ab	100 ab	100 abc	81 a	104 ab
10-25 mm	83 a	102 a	80 ab	87 ab	79 a	80 ab	88 ab	97 a	124 b
>25 mm	64 a	73 a	58 a	57 a	77 a	62 a	74 a	91 a	57 a

Conclusions

The MSW compost properties depended on particle size. Fine fractions (<2 mm) shown better quality than the mean compost; lower EC, Na content, C/N ratio, less glass and impurities indicated higher maturity and cleanness. Though this fine fraction had lower nutrient contents and the 0.5-2 mm fraction accumulated heavy metals, separation of the fine fraction would produce a compost more suitable for applications which require high stability compost, such as component of pot substrates for non edible (ornamental, forestry) crops. A more detailed study is needed to determine if a fraction between 2 and 5 mm would also be included in this class.

In the fractions of particle size above 2 mm, the deficient source separation in the studied composts caused a high presence of glass and impurities and heavy metal contents outside restrictive limits [1]. On the other hand, >2 mm fractions tended to be richer in fertilizing elements. Improving source separation and compost refining will render a product adequate for soil improvement and fertilization that accomplish future regulations.

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