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Chemical changes during vermicomposting (*Eisenia fetida*) of sheep manure mixed with cotton industrial wastes*

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Summary. Castings of *Eisenia fetida* from sheep manure alone and mixed with cotton wastes analysed for their properties and chemical composition every 2 weeks for 3 months and compared with the same manures in the absence of earthworms. The results showed that earthworms accelerated the mineralization rate and converted the manures into castings with a higher nutritional value and degrees of humification. The castings obtained from manure mixed with cotton wastes exhibited good agronomic quality, suggesting that this kind of industrial residue may be used in vermicomposting.

Key words: *Eisenia fetida* – Vermicomposting – Sheep manure – Cotton industrial wastes – Chemical composition

Various studies have been focused on the use of earthworms in the stabilization of organic residues such as sewage sludge, animal wastes, crop residues and industrial refuse (Mitchell et al. 1977; Kaplan et al. 1980; Riffaldi and Levi-Minzi 1983; Tomati et al. 1985). Under favourable conditions, wastes are converted into a homogeneous mass (castings) which may form a good soil conditioner with high nutritional value for plants.

The vermicomposting process is a result of the combined action of the earthworms and of microflora living in earthworm intestines and in the growth medium (Grapelli et al. 1983). Earthworms accelerate composting by bioturbation and aeration, giving a final product less rich nin nitrogen and organic matter but enhanced with available nutrients to plants. However, there are only a few literature references concerning the changes in chemical, biochemical and microbiological parameters during vermicomposting.

The purpose of this study was do determine the variations in chemical composition of sheep manure alone and in combination with industrial cotton wastes during 12 weeks of vermicomposting. These substrates are of major importance in the Barcelona area due to the highly developed textile and ovine livestock industries, which produce large quantities of cotton wastes and sheep manure.

Materials and methods

Field experiments were carried out on a farm producing commercially available earthworm compost, located in Calders (Barcelona, Spain) and following the commune production method.

Windrows (6 m long, 0.6 m wide and 0.4 m high) of sheep manure alone and mixed with flock cotton residues at a ratio of 3:1 were used. The experiments were carried out in the presence and absence of the earthworm *Eisenia fetida*, and continued for 12 weeks (earthworms obtained from Prisma Agropecuaria S.A., Manresa, Spain). The initial number of earthworms in the windrows was about 3000/m^2, including eggs, larvae and adults.

Samples were collected in sterilized closed glass bottles of 1-litre capacity each 2 weeks and then air-dried and homogenized.

Moisture content was determined by drying at 105 °C, the ash content by heating at 550 °C, total N by the Kjeldahl method in a Kjeltec Auto 1030 Analyzer and oxidizable C by oxidation with dichromate according to the method of Schollenberger (1931) revised by Hesse (1971). The pH was measured by a Crison pH-meter digital 501 using suspensions of the material in water, in the ratio 1:5 (w:v). Conductivity was determined by a Crison conductimeter 522 and cation exchange capacity (CEC) by the method of Bower et al. (1952). Humic substances were extracted according to Kononova (1966). Available P was analysed by the colorimetric method with molybdenum in sulphuric acid (Peech et al. 1947) and K^+ and Na^+ were determined with a Corning-EEL flame photometer.

The microbial population in each sample was assessed by determining the living cells (CFU, colony forming units) using the pour plate method in agar culture medium. Appropiate dilutions of each sample were prepared, 1 ml of each dilution being transfered to a

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Table 1. Changes in chemical properties during composting of sheep manure and sheep manure mixed with industrial cotton residues. The results are expressed on a dry matter basis and represent four replicates, with less than 4% variation

Time (weeks)	Sheep manure			Sheep manure + cotton residues		
	2	6	12	2	6	12
pH (H_2O)	8.9	8.4	8.2	8.8	8.5	8.2
Humidity (%)	64.4	61.2	58.0	65.8	52.7	52.2
Dry matter (%)	35.6	38.8	42.0	34.2	47.3	47.8
Conduc (mS/cm per 25 °C)	4.90	2.77	1.90	4.24	2.93	2.11
Salinity (‰)	3.14	1.77	1.22	2.72	1.87	1.35
CEC (mEq/100 g)	35.9	41.0	52.2	30.2	31.9	40.7
Ash (%)	43.7	41.5	47.6	38.5	41.8	47.2
Organic matter (%)	56.3	58.5	52.4	61.5	58.2	52.8
Ox C (%)	21.0	21.6	18.9	25.5	22.2	20.9
Humic acids (%)	12.1	12.1	18.0	11.8	12.7	14.4
Fulvic acids (%)	10.7	6.7	5.7	10.2	6.0	5.7
N_t (%)	2.26	2.35	2.12	2.48	2.21	2.19
C:N	9.3	8.8	8.9	10.3	10.1	9.5
Ass P (%)	2.99	3.08	4.46	2.71	3.10	3.81
K (%)	0.68	0.72	1.03	0.67	0.74	0.81
Na (%)	0.07	0.10	0.14	0.05	0.12	0.13
CFU (log)	8.11	7.54	8.30	8.58	8.77	9.02

Conduc, conductivity; CEC, cation exchange capacity; Ox C, oxidizable C; Ass, assimilable; CFU, colony forming units

Table 2. Changes in chemical properties of castings of *Eisenia fetida* derived during vermicomposting of sheep manure. The results are expressed on a dry matter basis and represent four replicates, with less than 4% variation

Time (weeks)	2	4	6	8	10	12
pH (H_2O)	9.1	9.0	8.4	8.3	8.0	7.2
Humidity (%)	68.6	59.9	59.6	58.9	56.8	56.3
Dry matter (%)	31.4	40.1	40.4	41.1	43.2	43.7
Conduc (mS/cm per 25 °C)	2.44	1.81	1.78	1.57	1.31	1.11
Salinity (‰)	1.56	1.16	1.14	1.00	0.84	0.71
CEC (mEq/100 g)	35.5	41.8	43.6	44.5	45.9	79.6
Ash (%)	44.2	44.4	52.2	48.2	49.3	53.0
Organic matter (%)	55.8	55.6	47.8	51.8	50.7	47.0
Ox C (%)	23.1	21.3	20.3	21.1	21.0	15.7
Humic acids (%)	12.9	12.3	16.9	14.2	20.2	21.8
Fulvic acids (%)	6.5	6.5	5.0	2.5	3.0	2.8
N_t (%)	2.00	2.07	1.94	2.16	2.09	1.76
C:N	10.5	10.3	11.0	9.8	10.1	8.9
Ass P (%)	3.19	3.08	3.24	3.28	3.42	4.37
K (%)	0.75	0.77	0.76	0.96	1.02	1.02
Na (%)	0.07	0.08	0.08	0.10	0.10	0.14
CFU (log)	7.48	7.90	7.46	6.46	6.34	6.94

Abbreviations as for Table 1

sterile Petri plate with 15 ml of Plate Count Agar melted and cooled (42–45 °C) being added. The agar was mixed thoroughly with the inoculum to distribute the cells uniformly. After solidification, the plates were inverted and incubated at 37 °C for 48 h. For each dilution level, three plates were inoculated.

The colonies were counted on the plates that contained 30–300 colonies. The number of colonies was multiplied by the dilution factor and reported as the number of CFU per gram of sample.

Results and discussion

Table 1 shows changes in the chemical properties of sheep manure and sheep manure mixed with industrial cotton wastes in the absence of earthworms during 12 weeks.

Tables 2 and 3 show changes in the chemical properties of earthworm castings from windrows without added cotton wastes (Table 2) and with added cotton wastes (Table 3) during 12 weeks.

The pH values of the castings decreased in both treatments, tending to neutrality. This decrease may be due to CO_2 and organic acids produced during microbial metabolism (Hartenstein and Hartenstein 1981).

Table 3. Changes in chemical properties of castings of *Eisenia fetida* derived during vermicomposting of sheep manure mixed with industrial cotton residues. The results are expressed on a dry matter basis and represent four replicates, with less than 4% variation

Time (weeks)	2	4	6	8	10	12
pH (H_2O)	8.7	8.6	8.5	8.5	8.0	7.7
Humidity (%)	68.9	60.1	54.1	51.2	50.8	49.5
Dry matter (%)	31.1	39.9	45.9	48.8	49.2	50.5
Conduc (mS/cm per 25 °C)	2.05	1.70	1.11	0.99	0.94	0.80
Salinity (‰)	1.31	1.09	0.71	0.63	0.60	0.51
CEC (mEq/100 g)	40.9	41.7	45.6	46.9	46.9	47.5
Ash (%)	40.3	48.2	45.9	46.9	52.6	59.9
Organic matter (%)	59.7	51.8	54.1	53.1	47.4	40.1
Ox C (%)	24.7	20.7	18.6	21.5	14.3	15.5
Humic acids (%)	12.2	11.8	12.5	14.7	15.7	18.9
Fulvic acids (%)	6.1	5.7	4.2	5.7	3.7	3.4
N_t (%)	2.06	1.93	1.89	2.01	1.56	1.71
C:N	11.4	10.7	9.8	9.8	9.2	9.1
Ass P (%)	2.75	3.20	3.29	3.47	3.52	4.31
K (%)	0.68	0.63	0.75	0.81	0.90	0.96
Na (%)	0.08	0.10	0.12	0.13	0.12	0.13
CFU (log)	9.17	9.70	9.77	8.64	6.59	6.28

Abbreviations as for Table 1

The moisture content during vermicomposting was reduced progressively, giving final values between 45% and 60%, ideal moisture content for a compost (Edwards 1983). This reduction was greater in castings than in manures.

The level of soluble salts was lower in the presence of earthworms. This indicates that vermicompost may be a suitable material for both soil amendments and plant growth, without producing toxic effects due to high salt concentrations.

The progressive increase in CEC was generally greater in castings than in manures. Different CEC values may in part reflect different mineralization rates of organic matter (Hartenstein and Hartenstein 1981) and the increase in humic acids which are known to have high CEC (Holtzclaw and Sposito 1979).

Total organic matter and oxidizable C contents decreased more markedly in the castings than in the manure; apparently, earthworms accelerated the decomposition of organic matter. A decrease in organic matter was also observed by Nardi et al. (1983) in castings from cow manure.

Total humic acid content increased more rapidly during the vermicomposting process than in treatments without earthworms. This confirms that earthworms increase the transformation of organic substances to stable humic compounds. The high humification of castings was reflected in the decrease of C:N ratio, in agreement with findings by Riffaldi and Levi-Minzi (1983).

The increase in mineral nutrients (P, Na, K) of the castings indicates that earthworms accelerated the mineralization of organic matter. Changes in the microbial population were observed during the vermicomposting, with a marked decrease after 8 weeks. These results are in agreement with those reported by Grapelli et al (1983), who suggested that earthworms selectively favour the microorganisms that are responsible for the transformation of organic substances in soils.

The final values of the parameters measured (Tables 2 and 3) indicate that the products obtained have a high fertilizing values. A comparison of their chemical properties shows that manure alone exhibited better fertilizing quality than castings obtained from manure mixed with cotton residues. This indicates that the characteristics of vermicompost depend on those of the original material.

Conclusions

Both types of vermicompost, compared with the materials from which they were derived, showed a lower pH, greater CEC, lower concentrations of soluble salts, organic matter and N and higher concentrations of total humic acids and mineral nutrients.

The lower pH and oxidizable C and the greater CEC may be related to the high level of total humic acids. During the vermicomposting process the mineralization rate appeared to be accelerated, as may be deduced from the increase in ash concentration. The vermicomposts were enriched in P, K and Na. Total N decreased but the decrease was partly balanced by a conversion into nitrate N (Grapelli et al. 1983). There may be additional losses from NH_3 volatilization due to pH values and/or N uptake into the earthworm biomass, as suggested by Hartenstein and Hartenstein (1981).

Finally, it may be concluded that vermicomposting of cotton wastes is an alternative method for recovery of industrial residues, at the same time producing a good, low-cost fertilizer.

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