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Physical and Chemical Characteristics of Fresh and Aged Spent Mushroom Compost

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***Abstract.* Selected physical and chemical properties of fresh spent mushroom compost were evaluated and compared to the properties of spent mushroom compost which was aged aerobically for 6 weeks. Bulk density, total pore space, total water at saturation, and percentage air space in fresh and aged spent composts were acceptable for plant growth. Both contained very high levels of soluble salts which were readily leachable. Concentrations of metals were acceptable, but concentrations of K, Ca, and Mg could lead to plant nutrient imbalances. Concentrations of NH_4-N in fresh spent mushroom compost were high.**

Spent mushroom compost (SMC) is a by-product of the mushroom industry. Mushroom compost is an organic material made from such materials as straw, horse manure, and peat. The fungal mycelia derive their nutrition from this medium and produce the fruiting bodies which are harvested. After about 45 days of growth, when yields drop and an economical crop is no longer being produced, the material is termed "spent" and must be replaced. The SMC generally is resterilized to control mushroom diseases and insects and then is offered for sale or dumped. About 35 million cubic meters of SMC are produced in the United States each year.

Researchers investigating the uses of SMC in potting mixes have advised against using SMC as obtained from mushroom houses (9, 14, 20). These researchers have suggested that the material be aged before use, but they give little information as to why or for how long it should be aged. The use of SMC as a field soil amendment has also been investigated, but the characteristics of the material have not been reported (15, 19).

The purpose of this study was to characterize both fresh and aged SMC, and to determine the potential usefulness of SMC in soilless potting mixes and as a field soil amendment.

Three batches of SMC, consisting of decomposed straw, horse manure, peat, limestone chips, gypsum, cottonseed meal, urea, and residual fungal mycelia, were obtained immediately following resterilization by the mushroom farm. Each batch represented one replication. Samples of "fresh" SMC were collected when each batch was received, and the remaining SMC was placed in four 200-liter drums for aging. To provide aeration, holes were drilled in the bottom of each drum, and each lid was left slightly ajar. To maintain aerobic conditions, the compost was turned by spading it into another drum every 3 days. Sufficient water was added as needed to maintain moisture at about 50% of wet weight, without leaching. This aerobic aging process was continued for 6 weeks, at which time "aged" samples were collected for analysis. Throughout the aging process, samples of SMC were collected as the compost was turned.

Samples were analyzed for 2 M KCl extractable NH_4-N using distillation methods (3). Additionally, electrical conductivity (EC) and pH of saturated paste extracts were measured (4).

To determine the rate at which salts could be leached, plexiglass tubes 20 cm deep and 4 cm in diameter were covered with cheesecloth at the bottom and filled to 16 cm with evenly compacted SMC. One volume (225 ml) of deionized water was poured on each column; the water which drained through was collected. This procedure was repeated weekly for 6 weeks. EC, pH, K, Ca, and Mg were measured in the leachates. After 6 weeks, the depth of the compost was measured, and the percentage of shrinkage was calculated.

Samples of air-dried SMC were digested

Table 1. Total elemental concentrations in fresh and aged spent mushroom composts.

	mmol/kg dry weight	
Element	Fresh SMC	Aged SMC
Nitrogen	1510 ± 170[z]	1580 ± 290
Phosphorus	180 ± 25	180 ± 30
Potassium	320 ± 45	305 ± 55
Calcium	740 ± 210	895 ± 105
Magnesium	275 ± 50	460 ± 60
Aluminum	180 ± 35	215 ± 10
Iron	67 ± 17	71 ± 5
Manganese	7.5 ± 2.3	7.1 ± 0.8
Zinc	1.7 ± 0.2	2.1 ± 0.1
Molybdenum	1.0 ± 0.2	1.4 ± 0.4

[z] ± SD.

Table 2. Physical characteristics of fresh and aged spent mushroom composts.

Physical characteristic	Fresh SMC	Aged SMC
Total pore space (% by vol)	87.1	86.3
Total water at saturation (% by vol)	63.2	65.5
Air space (% by vol)	24.0	20.8
Easily available water (10–50 cm) (% by vol)	12.6	22.6*
Water buffering capacity (50–100 cm)	1.9	2.1
Bulk density (g/cm^3)	0.256	0.293*
Specific gravity	2.05	2.12

*Fresh SMC significantly different from aged at 5% level.

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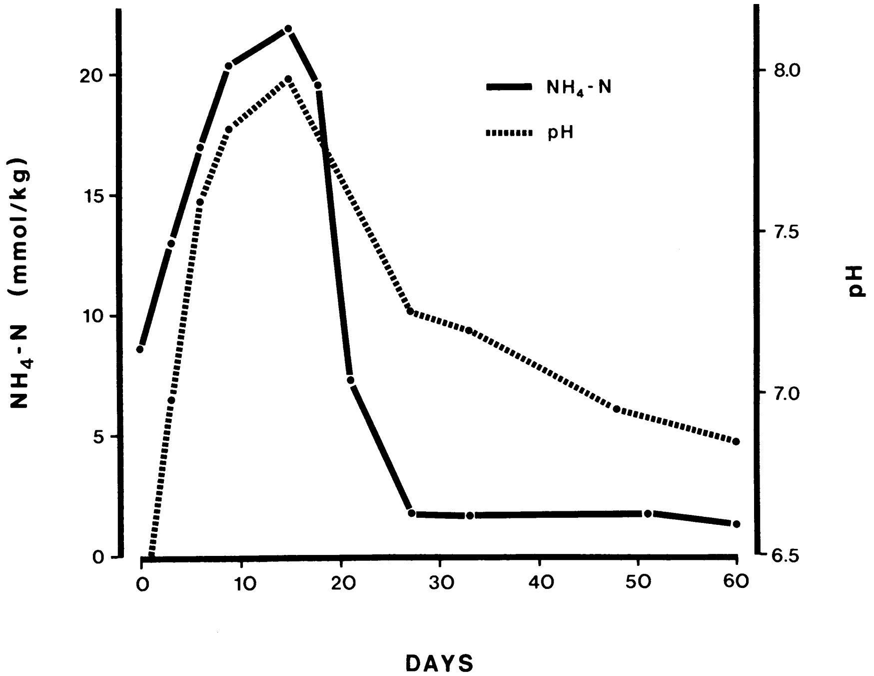

Fig. 1. Changes in the level of NH_4-N and in pH in aerobically aged spent mushroom compost over time.

by wet ashing to determine total elemental concentrations using atomic absorption spectrophotometry to measure K, Ca, Mg, Fe, Mn, Zn, Mo, Al, Ni, Cu, Cd, and Cr (1, 10). P was measured by vanadomolybdophosphoric yellow colorimetry (11). Total N was measured colorimetrically by the indophenol method after digestion with sulfuric acid and hydrogen peroxide (17).

Slight modifications in the methods of De Boodt and De Waele (8) were used to measure bulk density (BD), total pore space, percentage of air space, easily available water, and water buffering capacity. For BD, the compost was dried at 37°C, as recommended by Lockman (12), rather than at 105°, as recommended by De Boodt and De Waele (8), to prevent thermal decomposition of the organic matter. Specific gravity was determined using 50 cm^3 pycnometers and 24 hr of vacuum to remove air.

T tests were used to compare the characteristics of fresh and aged SMC.

As expected, the total elemental concentrations in fresh and aged SMC were similar (Table 1) and would provide low levels of fertilizer macronutrients. Each contained a trace of Co (less than 0.5 mmoles/kg). Concentrations of Cd, Ni, Cu, and Cr were too low to detect by the methods used, so heavy metal toxicities are not anticipated with the use of SMC.

Fresh SMC contained 47 ± 4% water by weight, and its BD averaged 0.17 g/cm^3. After aerobic composting for 6 weeks, the BD rose to 0.21 g/cm^3 (significantly different from fresh at the 1% level).

The volume of the fresh SMC in the plexiglass tubes shrank 28% during the 6-week leaching experiment, whereas the aged SMC shrank only 10% (different from fresh at the 0.1% level). A shrinkage of 28% is excessive for most uses of potting mixes. When combined with 50% vermiculite by volume, the shrinkage was only 10% with fresh SMC and 7% with aged SMC.

Total pore space, total water at saturation, and percentage of air space for both fresh and aged SMC generally were favorable for plant growth (Table 2). The amount of easily available water, defined as the quantity of water released between 10 and 50 cm of water of suction (8), is low for fresh SMC and adequate for aged SMC for use in soilless potting mixes. Water buffering capacity, the amount of water released between 50 and 100 cm, is quite low for both fresh and aged SMC. As the SMC aged and decomposed, BD increased.

The EC of a saturated paste extract from fresh SMC averaged 22 decisiemens per meter (1 dS/m = 1 mmho/cm), whereas the EC from aged SMC rose to 27 dS/m (Table 3). This increase was probably due to the release of salts as the organic matter decomposed (16). While the initial levels of salts in SMC were excessive for the growth of many plants, these salts were readily leachable (Table 3). After leaching with 3 volumes of water, the EC in leachates from both fresh and aged SMC had dropped to 4 dS/m. Further leachings resulted in a gradual drop to 1.5 dS/m.

An EC reading of 1 dS/m contains about 640 ppm total dissolved salts (18). Based on this approximation, the sum of the K, Ca, and Mg concentrations accounted for about 80% to 90% of the total dissolved salts present in the saturated paste extracts of SMC (Table 3). Nutrient imbalances might result from interactions among these cations (2). The concentration of K was high in the 1st leachate and lower in successive leachates. This reduction was expected because others have shown that monovalent cations are removed more readily by leaching than are divalent cations (16). The levels of Ca and Mg were relatively constant in successive leachates.

Other researchers have recommended using a $CaCl_2$ suspension as the extractant when determining the pH of samples containing high levels of ammonia (5). This procedure was not used, because preliminary studies showed that the pH of SMC measured with 1 N $CaCl_2$ was the same as the pH determined with deionized water. This similarity was probably due to the high levels of soluble salts already present in SMC. The pH of the leachates from fresh SMC was higher and more variable than that from aged SMC (Table 3). Because of the high pH, routine liming of field soils and potting mixes may be unnecessary when SMC is incorporated.

Variations in pH between fresh and aged SMC probably resulted from the changes in NH_4-N concentrations in SMC over time. Extractable NH_4-N in one batch of SMC increased from 8.9 mmol/kg (dry weight) when fresh, to over 20 mmol/kg after 15 days of aging, with a concomitant rise in pH (Fig. 1). After aging for 6 weeks, the level of NH_4-N dropped to 1 mmol/kg, with a corresponding decline in pH. The responses in other batches of SMC were similar. This phenomenon is commonly observed when potting media are steam-sterilized and when mixtures high in organic matter are not well-aerated (4, 6, 7). In this instance, it probably resulted from the resterilization of the SMC prior to shipment. Bacteria which convert NH_4-N to nitrites and nitrates are killed by heat, but the resting spores of some actinomycetes, which convert organic nitrogen to ammonium, are relatively resistant and survive the sterilization process (4). Populations of these ammonium-producing organisms

Table 3. Electrical conductivity, pH, and cation concentrations in successive leachates from fresh and aged spent mushroom composts.

Successive leachates	Fresh SMC					Aged SMC				
	EC[z]	pH	K[y]	Ca[y]	Mg[y]	EC[z]	pH	K[y]	Ca[y]	Mg[y]
0[x]	22.1	7.3	168	43.0	3.2	27.4**	6.7**	188	34.0	2.6
1	14.5	8.6	81	7.9	7.3	22.8**	6.6**	139*	16.3**	12.0
2	6.5	8.5	30	8.7	4.2	8.9*	6.5**	39*	8.2	5.3
3	4.0	7.9	11	9.5	3.9	4.2	6.5**	15	8.8	4.5

[z]Electrical conductivity, decisiemens per meter.
[y]Cation concentration, millimoles per liter leachate.
[x]Level before leaching, based on saturated paste extract.
*,**Fresh SMC significantly different from aged at 5% (*) or 1% (**) level.

proliferate following sterilization, causing a rise in NH_4-N and a rise in pH, as NH_4OH forms. Eventually, *Nitrosomonas* and the *Nitrobacter* species recolonize the compost, leading to the subsequent drop and stabilization in NH_4-N. Hydrogen ions then are released, as NH_4-N is converted to nitrites, thus causing a drop in pH.

If fresh SMC is used as a component of sterile potting mixes, the rise in NH_4-N levels, and the accompanying rise in pH, could be detrimental to plant growth (4, 13). The high shrinkage rate of fresh SMC may pose additional problems. These problems may explain why researchers investigating the uses of SMC in potting mixes have advised against using it directly from mushroom houses (9, 14, 20). Stockpiling SMC would probably not be effective in eliminating the toxic levels of NH_4-N. Davies and Owen (6, 7) showed that ammonia levels in steam sterilized soils which were left undisturbed remained high, even after 16 weeks, because little aerial contamination from nitrifying bacteria occurred at the surface of the undisturbed soil. This problem should not be encountered if SMC is used as a field soil amendment, because the nitrifying bacteria present in the soil would prevent a rise in NH_4-N.

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