CHAPTER 11

AN ABBREVIATED MUSHROOM COMPOSTING SYSTEM AIDED BY AN ACCELERATOR

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1. INTRODUCTION

Mushroom composting technology is currently facing a new problem of environmental pollution and several abbreviated composting procedures have been developed in response to this problem. Different terminologies such as express compost or PES (Laborde & Delmas, 1969), environmentally controlled compost or EC (Miller *et al.*, 1990), accelerated assisted compost or AAC (Nair & Price, 1990) etc, are currently being used to describe abbreviated composting processes. There have also been earlier attempts at developing rapid methods of composting (Till, 1962; Huhnke & Sengbush, 1968; Smith, 1974; Smith & Spencer, 1977) and today we have enough published documentation which indicate that the duration of composting can be reduced with little or no effect on mushroom production. The objective of an abbreviated composting system is to overcome the main disadvantages of the conventional process such as emission of objectionable odours, significant loss in dry matter and relatively low efficiency in process control. Limited or no outside composting and acceleration of the decomposition process are the main concepts that will enable us to achieve this objective.

This communication reports on some observations of the AAC process. We also point out that the mushroom industry will soon be subjected to environmental audit which will eventually lead to the greening of accountancy.

2. BACKGROUND TO THE AAC PROCESS

The AAC is characterised by the acceleration of biochemical and biological degradation of the basic compost materials. This has been brought about by the use of a specially formulated

TABLE 1. Compost formulation based on 1000 kg of wheat straw.

Raw material	Kg of fresh weight
Wheat straw	1,000
Poultry manure	883
Cottonseed hulls	444
Cottonseed meal	100
Gypsum	25
Lime	55

accelerator (proposed registered name: **PRITAN**). The accelerator encourages molecular changes in the basic materials and enables more-rapid decomposition. It also biochemically releases carbon for microbial activity.

The need for using a specially formulated accelerator stemmed from our preliminary trials on short composting. The raw ingredients (Table 1) were blended with the aid of a compost turner. Water was added to achieve a moisture content of 75% saturation. Steel bins with perforated basal plates were filled with the compost and mounted on a specially designed platform which enabled a sealed basal plenum to be created. The bins were placed in an enclosed chamber. The compost was then treated with aerated steam and composting carried out for 7 days. The pasteurisation was carried out at the end of 24 hours at 55°C (in the compost) for 3 hours and the conditioning temperature was 45 to 47°C for 5 days. The compost was cooled and spawned (with off-white hybrid strain) on the seventh day. We refer to this compost as short compost (SC). The spawned compost was filled into plastic bags, each bag containing 12 kg of compost. The bags were removed to environment-controlled experimental growing rooms and normal cropping procedures were carried out. The yield of mushrooms was recorded over a six-week cropping period.

The yield of mushrooms from the SC in two experimental trials is shown in Table 2 and it was relatively lower than that from the conventional compost. However, the analytical data of both the types of composts were similar in terms of total nitrogen and carbon, C:N ratio, pH and NH_4-N ammonium (Table 3).

The work of Holtz, Smith and Barkate (1975) pointed to the importance of lipid:protein ratio (L:P) as an index of compost quality. The reason for determining L:P ratio is based on the argument that the lipid content of the compost at spawning is the result of microbial activity. Therefore, one can assume that the majority of residual lipid at spawning is derived from microbial synthesis. The major sources of carbon for lipid synthesis are short chain or free carbohydrates. These compounds

TABLE 2. Yield of mushrooms from short and conventional composts.

Trial	Short Compost	Conventional Compost
a	9*	22
b	12	23

* Kg/sq.m
(after Nair and Price 1990)

TABLE 3. Analytical data of short compost and conventional compost at filling and at spawning.

	SC	CC	SC	CC
NH_4-N	0.18	0.18	0.07	0.01
Nitrogen(5)	1.52	1.87	2.01	2.58
Carbon (%)	47.80	37.70	37.00	36.10
Carbon:Nitrogen	24.80	20.16	17.61	13.99
Lipid:Protein	0.52	0.76	0.23	0.31
pH	7.50	7.60	7.00	7.10
Moisture (%) (approx.)	75.00	75.00	62.00	65.00

* SC = Short Compost; CC = Conventional Compost.
(after Nair and Price 1990)

are found in the compost as the hydrolytic products of cellulose. Based on the analysis of several compost samples, Holtz *et al.*, (1975) set the optimum level of L:P ratio at 0.8. If the ratio is > 0.8, it can be assumed that adequate carbon is available for microbial fat synthesis. However, if the value is <0.8 and, at the same time the C:N ratio is adequate, undercomposting (especially the breakdown of cellulose during composting) is indicated.

The L:P of the SC was < 0.8 and, since the C:N ratio of the compost was adequate, we concluded that the cellulose in the straw was not available for lipid synthesis by the resident microorganisms. Therefore, it was thought worthwhile to make the carbon available to the microorganisms by treating the straw chemically and biologically to hasten the release of straw cellulose.

In order to understand the need to use chemical, physical or biological agents to release straw cellulose, let us take a brief look at the structure of the straw. A lot of research has already been carried out by several workers on the anatomical and chemical characteristics of cereal straw. A characteristic of straw is that it mainly consists of highly lignified cell wall material which often constitutes up to 80% of the dry matter. These cell walls are mainly built up of structural polysaccharides and lignin. Plant cell walls generally contain three types of structural polysaccharides. In straw, the polysaccharide composition is rather simple with cellulose and xylans as the predominant components. Cellulose is one of the most abundant molecules in nature. Although it is apparently a simple molecule, being a linear polymer composed of up to 10,000 units (β-1, 4-linked glucopyranosyl), it is complicated by its three-dimensional structure. The conformation of cellulose favours the formation of bonds between the units in a chain and this bonding explains the mechanical strength of cellulose as well as its resistance to biological degradation.

The accessibility of cellulose to hydrolysis can be increased by treatment such as milling to increase the surface area, steaming or treatments with swelling chemicals to make the cellulose less crystalline and less hindered by associated compounds such as lignin or silica. Lignin is a bonding agent in the layers between cells and it contributes to further mechanical strength of cells.

There is, therefore, a need to treat straw in a suitable manner to release the tightly bonded cellulose for use by the microorganisms.

3. THE AAC PROCESS

The straw was chopped and blended with the other compost ingredients (Table 4) as uniformly

TABLE 4. Normal AAC formula.

		(kg)
Wheat straw	-	2000
Poultry manure	-	1500
Cottonseed hulls	-	800
Cottonseed meal	-	400
Gypsum	-	50
Lime	-	10
Crushed Sunflower seed	-	50
PRITAN accelerator 1.5 kg/1000 kg straw		
Moisture at fill = 72 to 75% saturation		

as possible. The mixture was then treated with the accelerator (PRITAN) and water added to bring the moisture content to 75% saturation. The compost mix was then subjected to the AAC process using steel bins as before and a commercial phase 2 tunnel. After filling the bins or the compost tunnel, the compost temperature was maintained at 42°C (range 42-47°C) for 72 hours followed by pasteurisation at 57°C (range 57-60°C) for 3 hours. The compost was then cooled to 25°C for spawning. The total duration of the composting was 5 days. Crops were grown in controlled environment commercial mushroom production rooms as well as in controlled environment experimental growing rooms.

The oxygen levels during the AAC process declined to 18.5% 6 hours after the start and then levelled at 20 to 20.5% for the remaining period. The concentration of NH_3 increased to 130 ppm 20 hours after fill and dropped sharply to 0 ppm during the following 45 hours. The NH_4-N decreased gradually from 375 ppm at the start to 150 ppm at the finish. The changes in the pattern of NH_4-N was reflected in the pH shift during the composting process. The level of total nitrogen increased steadily from 1.3 to 1.9 (average values). The ash content also increased from 14% to 23% during the AAC process. The compositional changes in AAC during processing showed a progressive breakdown and utilisation of carbon and nitrogen compounds (Table 5). The reduction in NH_4-N during the process points to microbial utilisation. The relatively high pH soon after the start of the

TABLE 5. Compositional changes in AAC during processing.

Day	Stage	NH_4-N (ppm)	N (%)	pH	Moisture (%)	Loss on ignition (%)	Lipids (%)
Friday	Fill	424	1.32	6.98	70.74	87.24	0.36
Saturday	-	536	1.40	8.31	68.97	85.21	0.43
Sunday	-	26	1.97	7.28	68.70	84.64	0.42
Monday	-	14	2.00	6.98	58.90	81.49	0.81
Tuesday	Spawning	12	2.00	7.00	65.00*	-	0.81

* Water added at spawning - (bag growing system).

TABLE 6. Comparisons of some physical characteristics of AAC and conventional compost.

Compost type	Replicate number	Wet bulk density (g cm^{-3})	Airfilled porosity (%)
AAC	1	1.00	76.2
	2	1.01	74.9
	3	0.99	73.6
	Mean	1.00^A	74.9
Conventional	1	1.04	70.4
	2	1.01	69.0
	3	0.99	66.0
	Mean	1.04^B	68.5

A = 1000 kgm^{-3}; B = 1040 kgm^{-3}

AAC process, generated by the high concentration of NH_3 at this stage, help in the disruption of covalent linkages between polysaccharides and lignin in the cell walls of the wheat straw (Iiyama *et al.,* 1990). This reaction, in conjunction with the cellulolytic activities of the enzymes and microorganisms in the accelerator PRITAN, help to breakdown the straw and allow microbial synthesis. The reduction in the C:N ratio from 26.8 at filling to 17.8 at spawning (Table 3) is indicative of microbial utilisation of carbon and nitrogen sources in the AAC. Such chemical changes lead to higher microbial biomass and aid in mushroom nutrition and compost productivity.

The wet bulk density of AAC appears to be similar to that of the conventional compost (Table 6). In fact, the density of AAC can be increased by increasing the manure: straw ratio (Table 7). Although increase in bulk density of conventional compost is correlated with increased mushroom production on a volume basis, composts of varying bulk densities produce similar crop yields based on the dry weight of compost (Randle & Flegg, 1985).

The yield of mushrooms from AAC ranged in the different trials from 120 kg/tonne of compost to 360 kg/tonne of compost. Data on the yield of mushrooms from 20 trials are presented in Table 8. All these trials were carried out in a commercial farm using the bag system of growing. The sudden drop in yield when the strain of spawn was changed from A357 to the S series (S35, S110 and S381) can be explained in part to inadequate crop management.

4. CONCLUSIONS

Observations made so far on the AAC process indicate that it can result in productive compost; however, consistent performance over a longer period of time is required before it can be considered a commercially viable system. The AAC process has overcome the common objections raised against abbreviated composting systems generally such as low yield of mushrooms, thermogenesis during spawn-run and casing, low bulk density, lack of nitrogen balance and non-selectivity. More importantly, the AAC process has overcome the odour and water pollution normally associated with the preparation of conventional compost. The fact that the mushroom industry will be subjected to

TABLE 7. Changes in the bulk density of AAC in relation to its formulation.

AAC mix		Weight of AAC per 1.67m^2 tray (kg)	Weight of conventional compost per 1.67m^2 tray	Decrease in compost/tray (%)
Wheat straw	27000[A]	115	160	28.1
Poultry manure	11000			
Gypsum	3500			
Lime	1000			
Wheat straw	2500[B]	154	160	3.7*
Poultry manure	10000			
Cottonseed meal	2000			
Gypsum1	2000			

* an increase of 24.4% of compost/tray.
A = N, 1.5%; C/N, 26.7
B = N, 1.9%; C/N, 20.7 (at fill)

TABLE 8. Yield of mushrooms from Accelerated Assisted Compost prepared in steel bins*.

Strain	Cropping days	Yield of mushrooms (kg) per bag	Yield of mushrooms (kg) per tonne of compost
A357	32	3.6	300
A357	24	4.3	350
A357	29	4.4	360
A357	41	3.7	310
A357	31	3.6	300
A357	32	2.4	200
A357	26	4.0	330
A357	27	3.9	320
A357	31	4.0	250
A357	31	3.2	200
A357	26	2.0	120
A357	27	2.2	130
A357	32	4.2	260
A357	29	3.7	230
S351	18	2.0	120
S110	24	2.6	160
S110	30	2.9	180
S381	30	2.3	140
A357	29	4.4	240
S381	30	4.7	260

* see text for description of bins (after Nair and Price 1990)

environmental audit is being increasingly realised. This means that a mushroom farm may be compelled to allocate funds for solving pollution problems on an annual basis. Anti-pollution expenditure would then be a normal component of company accounting procedure - the greening of accountancy. A farm would be judged as being well-managed on the basis of its commitment to antipollution strategy.

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REFERENCES

HUHNKE, W. & SENGBUSCH, R. VON (1968). Mushroom cultivation on non-compopsted nutritive substrates. *Mushroom Science* **7**, 405-409.

IIYAMA, K., LAM, T.B.T. & STONE, B.A. (1990). Phenolic acid bridges between polysaccharides and lignin in wheat internodes. *Phytochemistry* **29**, 733-737.

LABORDE, J. & DELMAS, J. (1969). *Bulletin de la federation nationale des syndicats agricoles des culticaterus de champignons* **184**, 2093-2109.

MILLER, F.C., HARPER, E.R., MACAULEY, B.J. & GULLIVERS, A. (1990). *Australian Journal of Experimental Agriculture* **36**, 287-296.

NAIR, N.G. & PRICE, G. (1990). Accelerated assisted compost - an abbreviated method of compost preparation. *Mushroom News*, November p.23-26.

RANDLE, P.E. & FLEGG, P.B. (1985). The effect of duration of composting on compost density and yield of mushrooms. *Scientia Horticulturae* **27**, 21-31.

SMITH, J.F. (1974). Selective substrates and rapid methods of preparation. *Mushroom Journal* **23**, 424-426.

SMITH, J.F. & SPENCER, D.M. (1976). Rapid preparation of compost suitable for the production of the cultivated mushroom. *Scientia Horticulturae* **7**, 197-205.

TILL, O. (1962). Cultivation of mushrooms on sterile substrates and reutilisation of spent compost. *Mushroom Science* **5**, 127-133.