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Full Length Research Paper

Temperature profiles of *Agaricus bisporus* in composting stages and effects of different composts formulas and casing materials on yield

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Three compost formulas using different activator materials were prepared for *Agaricus bisporus* cultivation. A locally available casing material known as peat of Bolu district and its different combinations with perlite were used. Temperature profiles of all mixtures during composting were measured at every composting stages at various depth in order to determine the compostability level of substrates. Compost temparature steadily increased until the 10th day of composting and maximum temperatures were recorded at the second turning stage of composting. The highest yield of (5124.1 g/kg) was recorded by wheat straw mixed with pigeon manure (formula number II) with the peat as casing material mixed with perlite (80:20 in volume). The most appropriate casing materials was appeared to be the peat of Bolu district mixed with perlite (80:20; in volume) for all of compost materials.

Key words: Composting, *Agaricus bisporus*, compost temperature, casing material, yield.

INTRODUCTION

The most widely grown edible mushroom *A. bisporus* is cultivated commercially on composted horse manure and wheat straw mixture (Eddy and Jakobs, 1976; Atkey and Wood, 1983; Sparling et al., 1982). Satisfactory development of spawn in unfermented substrate is prevailed by self generation of heat and competetion from other microorganisms. It is therefore necessary fermentation of substrate in order to produce a medium which will remain stable and in which quantity of readily available nutrients for competing microorganisms is considerably reduced. Compost for cultivation of *A. bisporus* is prepared from a mixture of organic materials subjected to a composting process for making it selective for the mushroom (Holtz and Scheisler, 1986; Lambert, 1941; Kachroo et al., 1979). In the past, many different materials have been used in the production of mushroom compost (Shandilya, 1979; Vedder, 1978; Tewari and Sohi, 1976; Block and Rao, 1962; Bist and Harsh, 1985).

The preparation of mushroom compost has for many years been divided into distinct phases; phase I during which raw material are mixed, wetted and stacked with considerable dry matter losses, and phase II, which includes pasteurization and conditioning treatment to produce a selective and pathogen free substrate (Randle and Hayes, 1972; Ross and Harris, 1983; Bech, 1973).

During phase I, fungal and bacterial activity produces large quantities of heat. Temperature ranges between ambient and 80 °C in distinct zones within a cross section of the compost stack. However, it has been proven as long ago as 1941 by Lambert that the most productive areas within the current low wide stacks were the regions of the compost within a temparature range of 45 to 55°C. Ross and Harris (1982) also found that ammonia disappeared most rapidly in the range of 40 to 45°C. Although disappearance was still fairly rapid over the range of 35 to 5°C. Temperatures above 50°C however prolonged the disappearance of ammonia. At this higher temperature and also at 40°C and below, non selective composts were produced.

Due to scarcity of horse manure, efforts have been made by scientists to develop an alternative based on vegetable origin named as "synthetic compost". Synthetic compost formulations remained standard for several years and scientist have recommended various formulations from different parts of the world depending upon their availability (Shandilya, 1979; Tewari and Sohi, 1976; Lambert, 1929; Sinden and Hauser, 1953).

The casing layer is an essential part of the total substrate in the artifical culture of *A. bisporus*. Although many different materials may adequately function as a casing layer, peat is generally regarded as the most suitable casing medium. Because of its unique water holding and structural properties, it is widely accepted as ideal for the purposes of casing. Peats has a neutral pH and because of its contention in organic matter and granular structure, stays porous even after a succession of watering, hold moisture, allows appropriate gaseous exchanges and supports microbial population able to release hormone-like substances which are very likely involved in stimulating the initation of fruit bodies (Eger, 1972; Hayes, 1981; Hayes et al., 1969).

A. bisporus requires two different substrates to form its fruit bodies; i.e the compost in which it grows vegatively and the poor nutrient casing soil in which the suitable physical, chemical and biological conditions stimulate the initation process and fruit body production (Segula et al., 1987).

The aim of the present work, therefore, was to determine the individual and mutual effects of controlled compost temperature, and of locally available casing material with the addition of perlite, and of different raw materials based on wheat straw on the cultivation of *A. bisporus.*

MATERIALS AND METHODS

Materials

Three composting formulas which were suggested by Işık and Bayraktar (1980) were evaluated. The formulas used in the experiments are detailed in Table 1. Percentage nitrogen (N) content of the composts formulas was adjusted to 2% prior to composting according to the formula (Lambert and Ayers, 1950; Rantcheva, 1972; Gerrits, 1974):

$$\text{Percentage N at start} = \frac{\text{Nitrogen (kg)} \times 100}{\text{Dry weight}} \quad 2$$

Composting process

Composting was carried out in two phases (Shandilya, 1982; Gerrits, 1984). Phase I (out-door composting): Raw materials were mixed and periodically turned according to the following schedule:

Day -4: Wheat straw was spread after wetting to the maximum capacity, on the composting yard to a height of 90 to 100 cm.

Day -2: Preliminary stack was turned and excess of water which runs off from the preliminary stack was collected and pumped back on the pile.

Day 0: Half quantitiy of wheat bran (formula I), pigeon manure (formula II) and corn stem (Formula III), urea and ammonium nitrate were added and proper aerobic stack was made 100 cm wide and 100 cm height. The length depends on the quantity of compost to be made. An understack air pipe was provided in the middle of the stack and each perforation properly checked to ensure equal air distribution continuously for 8 to10 h during making of the stack and then to 40 min cycle with 10 min on and 30 min off.

Day +5: First Turn: Half quantity of wheat bran (formula I), pigeon manure (formula II) and chopped corn stem (formula III), urea, ammonium nitrate were added, and entirely mollasses aerobic stack was made 100 cm wide and 100 cm height at equal distance from the perforated pipe. Compost was cut from each end with front loader and put equally in the central portion after passing through the turnning machine on both sides of the perforated pipe. Stack aeration system was running continuously for 8 to10 h and then in a 40 min cycle with 10 min on and 30 min off.

Day +9: 2nd turn: Grounded gypsum was spread on the stack. Understack aeration was used in the same way as in previous turns.

Day +11: 3rd turn: Free turning was made.

Day +13: 4rd turn: Free turning was made.

Day +15: 5th turn: Free turning was made.

After Phase I, compost was filled in bulk chambers.

Phase II (peak-heating of compost): Door and fresh air damper was closed and blower was put on for recirculation of air 150 to 250 cubic meter per 1000 kg of compost per h. Peak heating of compost in bulk chamber was done in three stages.

Prepeak heating stage

After 12 to15 h of filling the chambers, the temperature raised to 48 to 50°C and it was maintained for 36 to 40 h. These temperatures were obtained by the self-generation of heat in the compost without using live steam.

Peak heating stage

Temperature was raised to 57 to 58°C with the introduction of live steam and maintained for 4 h to ensure the proper pasteurization. Fresh air was introduced by opening the damper to 1/6 or 1/8th of its capacity.

Post peak heating stage

The temparature was reduced gradually to 48 to 52°C and maintained till there was no traceable ammonia in the compost, which took 4 days. Fresh air damper was opened to its full capacity and compost was cooled down to 25 to 28 °C at which the spawning was done. In this case, this temperature range was maintained by the self heating of compost.

Mushroom Cultivation Procedure

After bulking pasteurization, the compost was spawned with 10 g

Table 1. Treatments showing formulations for composting.

Formula number	Ingredients	Fresh weight (kg)	Moisture content (%)	Dry weight (kg)	Nitrogen (%)	Nitrogen (kg)
	Chopped Wheat straw	287	15	250	0.5	1.43
	Wheat bran	82	17	70	2.4	1.97
I	Ammonium nitrate	6.5	0	6.5	26	1.7
	Urea	4	0	4	44	1.76
	Mollasses	15	50	10	1.3	0.2
	Gypsum	15	0	15	0	0
	TOTAL			**355**		**7.06**
	Wheat straw	287	15	250	0.5	1.43
	Pigeon manure	82.5	17	66	2.4	2.88
II	Ammonium nitrate	5	0	5	26	1.3
	Urea	3	0	3	44	1.32
	Mollasses	15	50	10	1.3	0.2
	Gypsum	15	0	15	0	0
	TOTAL			**353**		**7.13**
	Wheat straw	287	15	250	0.5	1.4
	Chopped corn stem	82.5	17	70	2.4	2.9
III	Ammonium nitrate	10	0	10	26	1.5
	Urea	6.5	0	6.5	44	1.5
	Mollasses	15	50	10	1.3	0.2
	Gypsum	15	0	15	0	0
	TOTAL			**362**		**7.38**

mycelium (Type Horst U1) per kg then filled into plastic bags as 10 kg wet weight basis. During spawn run, the temperature of the inlet air is automatically regulated by a cooling surface in the recirculation canal such that the compost temperature is maintained at 24 to 25°C with a minimum supply of fresh air. The 12 days of vegetative growth took place in spawning room arranged to 25°C temperature, and 90% relative humidity without ventilation (Hayes and Shandilya, 1977; Vedder, 1978). The spawned compost was then cased with peat of Bolu, Yeniçağa district mixed with perlite as 80 to 20 and 70 to 30 volume basis. Before casing, chalk was added to give a pH of 7.5 to 8. Casing was 3 cm in thickness. After 7 days, the temperature was lowered to 16°C, with ventilation, for pinhead production. Watering after casing was done as suggested for commercial growth (Randle, 1984; Shandilya, 1986).

After pinhead development, following picking periods of mushroom along with four flushes the yield data were recorded for 60 days with the following equation:

$$\text{Yield} = \frac{\text{Fresh mushroom weight}}{\text{Fresh compost weight}} \times 100$$

Measuring of inner compost temparatures

Inner compost temperatures were measured as an indicator of microbial activity within the compost piles. Along the lengthwise, 30 cm from the points of compost pile three heights of 30 cm, 60 cm and 90 cm were marked as in the Figure 1. And also, three heights were determined just in the middle of compost along the length wise for temperature measurements which were made everyday at 24 h intervals. Thus, 27 temperature measurement points were selected in total (Figure 1), and 432 total measurements were made for each compost formula.

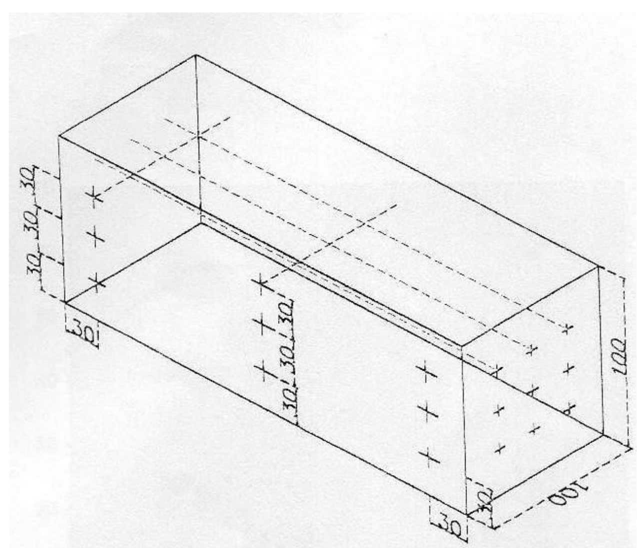

Figure 1. Measuring points of inner compost temperature

Table 2. Inner temperature values of wheat straw mixed with wheat bran (Formula I).

Composting phase	Day	Daily temperature °C		Temperatures of turning	
		Mean	St. Dev.	Mean	SD*
1th	1	36.3	0.3	41.5	4.7
	2	38.7	0.0		
	3	39.1	0.4		
	4	40.5	0.1		
	5	46.8	1.3		
	6	47.6	0.0		
2nd	7	49.9	1.9	53.0	3.3
	8	52.0	0.5		
	9	54.3	0.4		
	10	56.7	0.2		
3rd	11	47.7	1.5	45.8	2.7
	12	43.9	0.2		
4th	13	40.4	1.6	39.8	0.8
	14	39.3	1.1		
5th	15	36.1	0.2	34.4	2.4
	16	32.7	0.7		

Table 3. Inner temperature values of wheat straw mixed with pigeon manure (Formula II).

Composting phase	Day	Daily Temperature °C		Temperatures of turning	
		Mean	St. Dev.	Mean	SD
1st	1	33.5	0.1	44.7	7.7
	2	38.0	0.7		
	3	43.8	1.7		
	4	48.1	0.9		
	5	51.5	1.3		
	6	53.3	0.9		
2nd	7	54.9	3.2	57.3	2.0
	8	56.3	1.7		
	9	58.1	0.0		
	10	59.8	0.3		
3rd	11	55.4	0.1	53.5	2.7
	12	51.6	0.3		
4th	13	48.1	0.3	45.8	3.3
	14	43.5	1.6		
5th	15	38.2	2.6	36.5	2.3

RESULTS AND DISCUSSION

Inner compost temperature profiles of composts

The inner temperature degrees of the mean values of 27 measuring points determined for the composts of the Formula I, the Formula II and for the Formula III are given Tables 1-3.

Average temperature degrees of the turning stages for three compost formula are also given Figure 2. The highest temperature degrees of all compost formulas were recorded at the second turning stage. It might probably be due to addition of mollasses at the 6th day of composting. Increased temperature at this stage (7th to 10th days of composting) is an indicator for a rapid and exothermic microbial activity within compost layers. This may be a critical stage for decomposition of carbohydrates necessary to produce a selective substrate environment for mushroom growing. These results are consistent with the previous findings (Yalinkiliç et al., 1994).

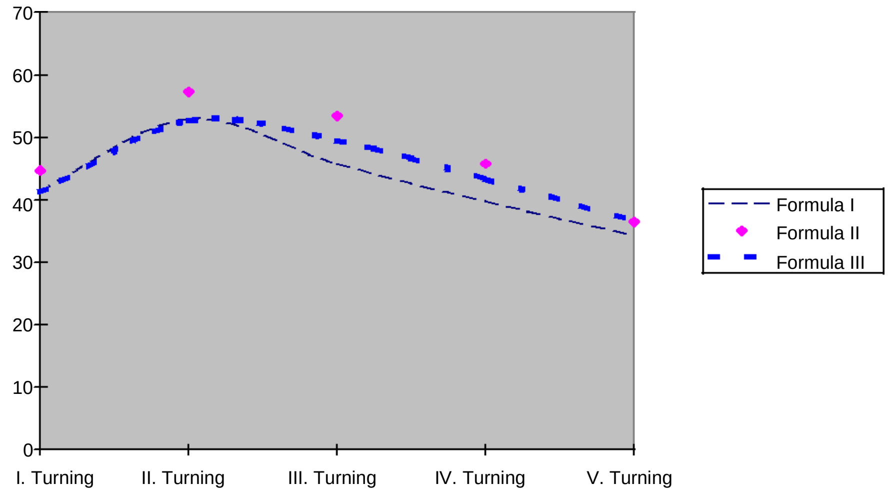

Figure 2. Inner compost temperature of formula I , formula II and formula III

Table 4. Inner Temperature values of wheat straw mixed with chopped corn stem (Formulae III)

Composting Phase	Day	Daily temperature °C		Temperatures of turning	
		Mean	St. Dev.	Mean	SD
1st	1	34.5	0.5	41.3	6.4
	2	33.1	0.1		
	3	40.6	1.3		
	4	44.1	0.3		
	5	47.6	0.3		
	6	48.2	4.8		
2nd	7	50.3	0.1	52.7	1.9
	8	52.1	2.1		
	9	53.8	1.1		
	10	54.5	2.4		
3rd	11	50.9	0.4	49.6	1.8
	12	48.4	0.1		
4th	13	43.6	2.2	43.4	0.2
	14	43.3	3.7		
5th	15	38.1	6.1	36.7	1.9
	16	35.4	4.8		

As it is seen from to Figure 2, inner temperature degrees obtained from the compost piles steadily rose to a peak level at the 1st and 2nd turning stages followed by gradual decrease. Composting was completed at 16 days for all formulas (I, II and III) with an end temperature level of 31 to 36°C.

Effects of various compost formulas and casing materials on the yield properties

In this study, three compost formulas and locally available casing materials peat and perlite were used to determine their effect on mushroom yield. Average yield data were recorded up to 60 days and 4 flushes are given Table 4.

Among the casing mixture, peat mixed with perlite, 80:20 in volume, gave the highest mushroom yield followed by the mixtures of 70: 30 and 50: 50. For all compost formulas used, sole peat as casing material gave lowest yields indicating contributory effect of perlite on mushroom yield (Yalinkiliç et al., 1984) probably due to the high moisture holding capacity of perlite (Yalinkiliç et al., 194; Baysal, 1999). On the other hand, among the compost formulas, Formula II gave the maximum mushroom yield followed by wheat straw

Table 5. Yield values different compost types and casing materials.

Compost types[a]	Casing Materials (%, v/v)	Yield (g/Kg)[b] Mean ± Sd [c]
Formula I	Turf of Bolu (100) (TB)	2656.7±443.0
	Turf of Bolu +Perlite (70:30)	2952.7±354.5
	Turf of Bolu+perlite (80:20)	3248.7±605.9
Formula II	Turf of Bolu (100) (TB)	2388.2±355.1
	Turf of Bolu +Perlite (70:30)	4831.6±283.6
	Turf of Bolu+perlite (80:20)	5124.1±419.3
Formula III	Turf of Bolu (100) (TB)	1922.3±399.5
	Turf of Bolu +Perlite (70:30)	2174.0±525.7
	Turf of Bolu+perlite (80:20)	3188.2±413.4

Note: Small letters given as superscript over spawn running, pin head formation fruit body formation and total yield values represent homogenity groups obtained by statistical analysis with similar letters reflecting statistical insignificance at the 95 % confidence level.
[a] Composts were filled into plastic bags as 10 kg weights basis;
[b] results reflect observations of five plastic bags.
[c] Standard deviation.

mixed with wheat bran (Formula I) and, the wheat straw mixed with chopped corn stem (Formula III) (Table 5).

In the present study, three types of composts were prepared and locally available casing materials were used to grow *A. bisporus.*

Results revealed that all the organic ingredients used in different formulations composted well within 16 days of outdoor composting, resulting in the formation of very vigorous and selective compost supporting the growth of *A. bisporus* mycelium.

In conclusion, as a result of microbial activities within composts, measured inner temperatures of all compost formulas reached the highest level at the 2 nd turning stage after mollasses addition. Acceleration effect of molasses in microbial activity was therefore evident, while perlite appears to be an acceptable material that can be mixed with the peat (Baysal, 1999).

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