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Full Length Research Paper

Cultivation of *Agaricus bisporus* on some compost formulas and locally available casing materials. Part II: Waste tea leaves based compost formulas and locally available casing materials

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Three compost formulas (formula I, formula II, and formula III) based waste tea leaves and using some activator materials such as wheat bran, chicken manure and pigeon manure were studied for *Agaricus bisporus* cultivation. Some locally available peats such as peat of Bolu, peat of Agacbasi, peat of Caykara and theirs mixture (80:20; volume : volume) with perlite were used. Temperature values of all compost formulas during composting process were measured to determine the compostability level. According to results, compost temparature steadily increased until the 8th, 9th, and 9th day of composting for formula I, formula II, and formula III, respectively. The maximum compost temperature values were measured for all compost formulas at the second turning stage of composting process. The highest compost temperature values were measured prepared from a mixture of waste tea leaves and wheat bran (formula I). The best mushroom yield was obtained by a mixture of waste tea leaves and pigeon manure with the peat of Caykara and perlite mixture as casing material. Peat of Caykara gave higher mushroom yield than those of other peats.

Key words: Waste tea leaves, composting process, compost temperature, peat, activator materials.

INTRODUCTION

Compost for the production of white button mushrooms *Agaricus bisporus,* is produced from wheat straw, straw-bedded horse manure, chicken manure and gypsum (Straatsma et al., 2000). Compost for cultivation of *A. bisporus* is prepared from a mixture of organic materials subjected to a composting process for making it selective for growth *A. bisporus* (Colak, 2004; Holtz and Scheisler, 1986; Lambert, 1941; Kachroo et al., 1979). 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).

Due to scarcity of hourse manure, many efforts have been made by researchers to develop its alternative materials named as “synthetic compost”. Synhetic 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).

Casing soil has an important role in the cultivation of *A. bisporus* (Gulser and Peksen, 2003). Although many different materials may adequately function as a casing layer, peat is generally used and recommended as a good casing medium. This is because its unique water holding and structural properties makes it widely accep-

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Table 1. Waste tea leaves based compost formulas.

Formula	Ingredients	Fresh weight (kg)	Moisture content (%)	Dry weight (kg)	Nitrogen	Nitrogen (kg)
I	Waste tea leaves	448.0	12.0	400.0	2.3	9.20
	Wheat bran	132.0	17.0	113.0	2.4	2.71
	Ammonium nitrate	3.67	0.0	3.67	26	0.95
	Urea	2.17	0.0	2.17	44	0.95
	Mollasses	24.0	50.0	16.0	1.3	0.20
	Gypsum	24.0	0.0	24.0	0.0	**0.0**
	TOTAL			**559.80**		**14.01**
II	Waste tea leaves	448.0	12.0	400.0	2.3	9.20
	Chicken manure	135.0	20.0	113.0	1.7	1.92
	Ammonium nitrate	5.0	0.0	5.0	26	1.30
	Urea	3.0	0.0	3.0	44	**1.32**
	Mollasses	24.0	50.0	16.0	**1.3**	0.20
	Gypsum	24.0	0.0	24.0	**0.0**	**0.0**
	TOTAL			**561.00**		**13.49**
III	Waste tea leaves	448.0	12.0	400.0	2.3	9.20
	Pigeon manure	134.0	18.0	113.0	3.5	3.95
	Ammonium nitrate	1.0	0.0	15.0	26	0.26
	Urea	0.6	0.0	10.0	44	0.26
	Mollasses	24.0	50.0	16.0	1.3	0.20
	Gypsum	24.0	0.0	24.0	0.0	0.0
	TOTAL			**578.00**		**13.87**

ted as ideal for the purposes of casing (Colak, 2004; Baysal 1999).

The aim of the this study was to determine the individual and mutual effects of controlled compost temperature, and of locally available peats with the addition of perlite, and of different raw materials based waste tea leaves on cultivation of *A. bisporus*.

MATERIALS AND METHODS

Table 1 shows three compost formulas based waste tea leaves. In this study, peats such as Peat of Bolu, peat of Agacbasi, and peat of Caykara were supplied, Bolu district, Agacbasi district (Surmene-Trabzon), and Caykara district (Trabzon), in Turkey, respectively. Composting process was carried out within two phases (Shandilya, 1982):

Phase I (outdoor composting): Waste tea leaves and activator materials were mixed and periodically turned according to the following schedule (Colak, 2004):

Day –4: Waste tea leaves were spread after wetting to the maximum capacity, on the composting yard to a height of 90 – 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: Added half quantitiy of wheat bran (formula I), chicken manure (formula II) and pigeon manure (Formula III), urea and ammonium nitrate and proper aerobic stack was made 100 cm wide and 100 cm height. The length will depend 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 –10 h during making of the stack and then to 40 min cycle with 10 min on and 30 min off.

Day +5: First Turn: Added half quantity of wheat bran (formula I), chicken manure (formula II) and pigeon manure (formula III), urea, ammonium nitrate 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 - 10 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.
Day +17: 5th turn: Free turning was made.
Day +19: 5th turn: Free turning was made.
Day +21: 5th turn: Free turning was made.
Day +23: 5th turn: Free turning was made.
Day +25: 5th turn: Free turning was made.
After Phase I, compost was filled in bulk chambers.

Phase II (peak-heating of compost): Phase II completed either by hot air and steam. First 48 – 50°C temperature was maintaned 36 – 40 h. After, air temperature rose to 58 – 60°C. Then, steam injection was stopped and the temparature was reduced gradually to 48 – 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 – 28°C at which the spawning was done. In this case, this temperature range was maintained by the self heating of compost.

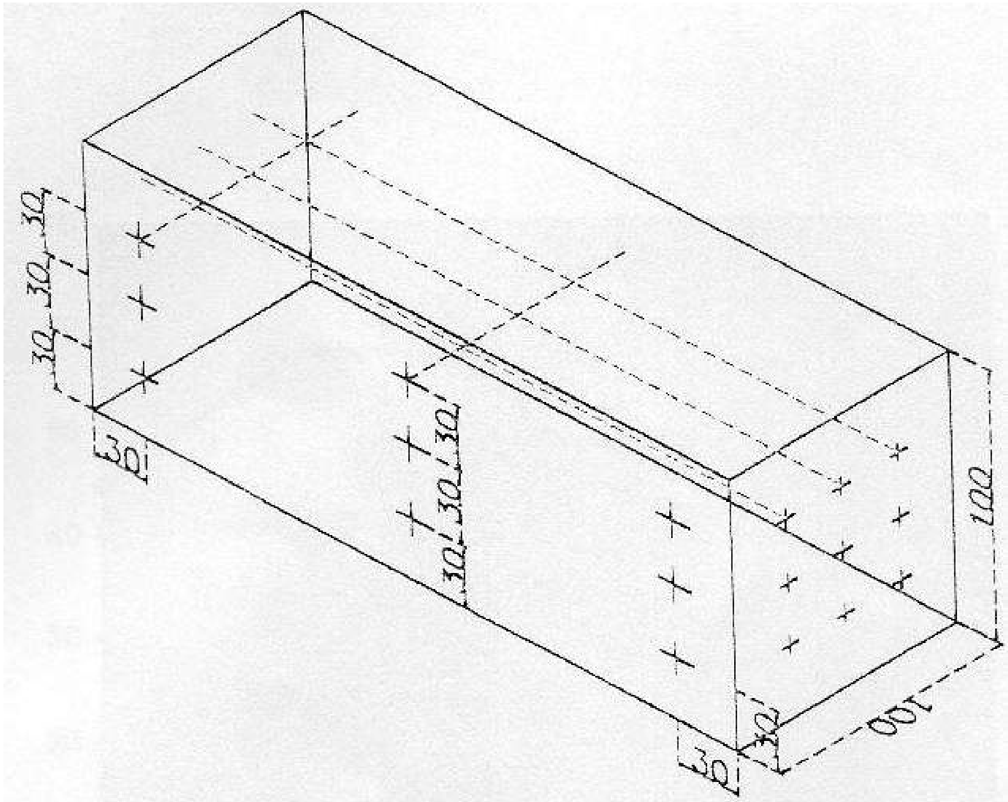

Figure 1. Measuring points of compost temperature.

After pasteurization, the compost was spawned with 30 g mycelium (Type Horst U1) per kg then filled into plastic bags as 7 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 24-25°C with a minimum supply of fresh air. Spawning room arranged to 25°C temperature, and 90% relaative humidity without ventilation (Hayes and Shandilya, 1977). After 18 days of mycelial growth, a 3 cm layer casing material covered over the compost. Before casing, chalk was added to give a pH of 7.5-8. 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).

Percentage nitrogen (N) content of the composts formulas was arranged to 2.5%. Nitrogen contents of compost formulas were determined following equation:

$$\text{Percentage N at start} = \frac{\text{Nitrogen (kg)} \times 100}{\text{Dry weight (kg)}} \cong 2.5$$

Inner compost temperatures were measured during composting process along the lengthwise, 30 cm from the points of compost pile three height as 30 cm, 60 cm and 90 cm were marked. Also, three heights were determined just in the middle of compost alongs the length wise for temperature measurements which were made everyday at 24 h intervals (Figure 1).

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

RESULTS AND DISCUSSION

Compost temperature values

The compost temperature values of the formula I, formula II, and formula III are given in Tables 2 - 4. Also, Figure 1 shows the temperature values of the turning stages for three compost formulas. Results showed that the highest temperature values of all compost formulas were measured at the second turning stage. It might be probably due to addition of mollasses at the 6th day of composting process. Increased temperature at this stage is an indicator for a rapid and exothermic microbial activity within compost layers that might be critical stage for decomposition of carbohydrates for necessary to produce a selective substrate environment for mushroom growing. These results are consistent with the previous findings reported by earlier researchers (Yalinkilic et al., 1994; Baysal, 1999; Colak, 2004).

The temperature values of all compost formulas steadily rose to a peak level at the 1st and 2nd turning stages followed by gradual decrease determined. Composting process was completed at 25 days, 17 days, and 21days for formula I, formula II, and formula III, respecttively, with the end temperature levels of between 43-45°C. Ammonia is a respiration inhibitor, its complete

Table 2. Temperature values of waste tea leaves mixed with wheat bran (Formula I).

Composting Day stage	Day	Daily temperature values (°C)	Temperature values of turning stages (°C)
I	1	60.8 ± 6.90^{defg}	69.2 ± 2.93^{ef}
	2	65.0 ± 13.1^{efghı}	
	3	69.8 ± 4.45^{klmn}	
	4	67.1 ± 2.25^{ghıj}	
	5	71.3 ± 2.44^{lmno}	
II	6	77.4 ± 3.84^{rs}	82.3 ± 3.95^{h}
	7	84.8 ± 3.51^{t}	
	8	86.2 ± 4.11^{t}	
	9	81.1 ± 3.24^{st}	
III	10	76.2 ± 2.81^{prs}	74.1 ± 2.89^{g}
	11	72.1 ± 2.04^{nop}	
IV	12	68.3 ± 1.85^{klm}	68.7 ± 0.63^{f}
	13	69.2 ± 2.11^{klm}	
V	14	66.2 ± 3.10^{fghı}	64.3 ± 2.68^{ef}
	15	62.4 ± 1.74^{defgh}	
VI	16	63.8 ± 2.03^{efgh}	63.4 ± 0.56^{de}
	17	63.0 ± 2.64^{defgh}	
VII	18	59.6 ± 1.84^{cdef}	59.1 ± 0.63^{cd}
	19	58.7 ± 1.66^{cde}	
VIII	20	58.0 ± 2.36^{cde}	57.1 ± 1.20^{bc}
	21	56.3 ± 1.86^{cd}	
IX	22	53.4 ± 2.11^{bc}	53.0 ± 0.49^{a}
	23	52.7 ± 1.45^{bc}	
X	24	48.5 ± 1.84^{ab}	45.8 ± 3.53^{b}
	25	43.3 ± 1.60^{a}	

release from the compost is critical at the end of the composting process (Flegg and Wood, 1985). Ross and Harris (1982) found that ammonia disappeared most rapidly in the range of 40 to 45°C. In this study, the highest temperatures degrees obtained were 86.2, 70.3 and 77.2°C for formula I, formula II, and formula III, respectively. Colak (2004) reported that during phase I, fungal and bacterial activity produces large quantities of heat. Temperature ranges between ambient and 80°C in distinct zones within a croos section of the compost stack. Jess et al. (2006) reported that during phase I composting process, the raw ingredients are mixed and wetted to allow the microbial flora to break down the straw. Owing to microbial activity, the centre of the compost stack may reach temperatures of 70-80°C, which is sufficient to kill pests and pathogens in the raw materials. In our study, a mixture of waste tea leaves and wheat bran gave the highest compost temperature values followed by a mixture of waste tea leaves and pigeon manure and a mixture of waste tea leaves and chicken manure. Baysal (1999) reported that the highest compost temperature values of some compost formulations prepared from a mixture of wheat straw based and same activator materials such as wheat bran, chicken manure, and pigeon manure were 71.9, 72.3, and 70.5°C, respectively.

Mushroom yield values

Mushroom yields of three compost formulas and some casing materials are given in Table 5. The mushroom yield was significantly higher from the peat and perlite mixture for all compost formulas than those of other casing materials. This indicates that perlite in casing soil can enhance significantly ($P \leq 0.05$) the mushroom yield by high moisture holding capacity of perlite (Yalinkilic et al., 1994; Baysal, 1999). Colak (2004) reported that a mixture of peat with perlite in 80:20 (v/v) and 70: 30 (v/v) ratios provided higher yield than sole peat using a casing material. Vijay et al. (1988) reported that a good casing should have a high water holding capacity and porosity. Noble and Dovrovin-Pennington (2005) found that substitution with 25% (v/v) coal tailings in black peat-based casings resulted in an increase in mushroom dry matter content without a corresponding yield loss. In this study, among the compost formulas, a mixture of waste

Table 3. Temperature values of waste tea leaves mixed with chicken manure chicken manure (Formula II).

Composting stage	Day	Daily temperature values (℃)	Temperature values of turning stages(℃)
I	1	50.5 ± 10.78^{bc}	59.6 ± 5.20^{b}
	2	62.2 ± 4.51^{de}	
	3	61.3 ± 4.06^{de}	
	4	60.9 ± 3.75^{de}	
	5	63.4 ± 3.73^{ef}	
II	6	66.0 ± 2.20^{ef}	67.7 ± 1.92^{c}
	7	66.6 ± 3.13^{ef}	
	8	68.2 ± 2.94^{ef}	
	9	70.3 ± 3.16^{g}	
III	10	67.3 ± 2.84^{ef}	65.2 ± 2.90^{c}
	11	$64.6 \pm 2.01^{fgh\imath}$	
IV	12	60.6 ± 2.84^{ef}	61.9 ± 1.83^{b}
	13	55.2 ± 1.86^{cd}	
V	14	51.4 ± 3.66^{bc}	48.7 ± 3.39^{a}
	15	46.3 ± 4.84^{ab}	
VI	16	45.2 ± 2.11^{ab}	43.7 ± 2.05^{C}
	17	42.3 ± 1.80^{a}	

Values are in mean ± SD (standard deviation).
Small letters given as superscript represent homogenity groups obtained by statistical analysis with similar letters reflecting statistical insignificance at the 95% confidence level.

Table 4. Temperature values of waste tea leaves mixed with pigeon manure (Formula III).

Composting Day stage	Day	Daily temperature values (℃)	Temperature values of turning stages (℃)
I	1	55.0 ± 4.75^{bcdef}	59.8 ± 3.47^{cd}
	2	57.4 ± 6.61^{cdefg}	
	3	$62.3 \pm 4.72^{efgh\imath}$	
	4	61.7 ± 3.84^{defgh}	
	5	$62.9 \pm 3.11^{fgh\imath}$	
II	6	$66.5 \pm 5.24^{h\imath j}$	71.2 ± 4.85^{e}
	7	$68.8 \pm 4.93^{h\imath jk}$	
	8	72.0 ± 5.11^{jk}	
	9	77.2 ± 4.74^{k}	
III	10	$70.8 \pm 3.52^{\imath jk}$	69.3 ± 2.05^{e}
	11	$67.9 \pm 3.85^{h\imath j}$	
IV	12	$64.6 \pm 1.71^{gh\imath j}$	63.4 ± 1.69^{d}
	13	$62.2 \pm 4.23^{efgh\imath}$	
V	14	$67.6 \pm 2.71^{h\imath j}$	60.6 ± 9.05^{cd}
	15	54.2 ± 10.9^{bcde}	
VI	16	58.1 ± 3.09^{cdefg}	55.0 ± 4.31^{bc}
	17	51.7 ± 1.57^{a}	
VII	18	53.3 ± 2.20^{bcd}	52.2 ± 1.55^{b}
	19	51.1 ± 2.14^{abc}	
VIII	20	48.3 ± 4.11^{ab}	45.7 ± 3.60^{a}
	21	43.2 ± 3.94^{a}	

Values are in mean ± SD (standard deviation).
Small letters given as superscript represent homogenity groups obtained by statistical analysis with similar letters reflecting statistical insignificance at the 95% confidence level.

Table 5. Yield values compost formulas and casing materials.

Compost formulas	Casing materials	Mixture ratio (%, in volume)	Yield** Mean (gr) ± SD***
Formula I*	Peat of Bolu	100	1321.3 ± 163.2 [abcd]
	Peat of Agacbasi	100	1449.7 ± 62.7 [abcdef]
	Peat of Caykara	100	1676.0 ± 23.96 [efgh]
	Peat of Bolu + perlite	(80:20)	1277.7 ± 54.5 [abc]
	Peat of Agacbasi + perlite	(80:20)	1537.0 ± 162.8 [bcdefgh]
	Peat of Caykara + perlite	(80:20)	1704.2 ± 90.8 [fgh]
Formula II	Peat of Bolu	100	1198.2 ± 89.7 [a]
	Peat of Agacbasi	100	1256.5 ± 119.8 [ab]
	Peat of Caykara	100	1597.7 ± 300.9 [defgh]
	Peat of Bolu + perlite	(80:20)	1418.0 ± 25.9 [abcdef]
	Peat of Agacbasi + perlite	(80:20)	1794.0 ± 291.7 [gh]
	Peat of Caykara + perlite	(80:20)	1661.0 ± 186.9 [efgh]
Formula III	Peat of Bolu	100	1330.7 ± 52.2 [abcd]
	Peat of Agacbasi	100	1497.2 ± 141.7 [bcdefg]
	Peat of Caykara	100	1395.2 ± 87.2 [abcde]
	Peat of Bolu + perlite	(80:20)	1533.5 ± 89.9 [bcdefgh]
	Peat of Agacbasi + perlite	(80:20)	1561.7 ± 120.0 [cdefgh]
	Peat of Caykara + perlite	(80:20)	1829.0 ± 274.0 [h]

Small letters given as superscript over yield values represent homogenity groups obtained by statistical analysis with similar letters reflecting statistical insignificance at the 95% confidence level.
*Composts were filled into plastic bags as 7 kg weights basis.
**Results reflect observations of four plastic bags.
***Standard deviation.

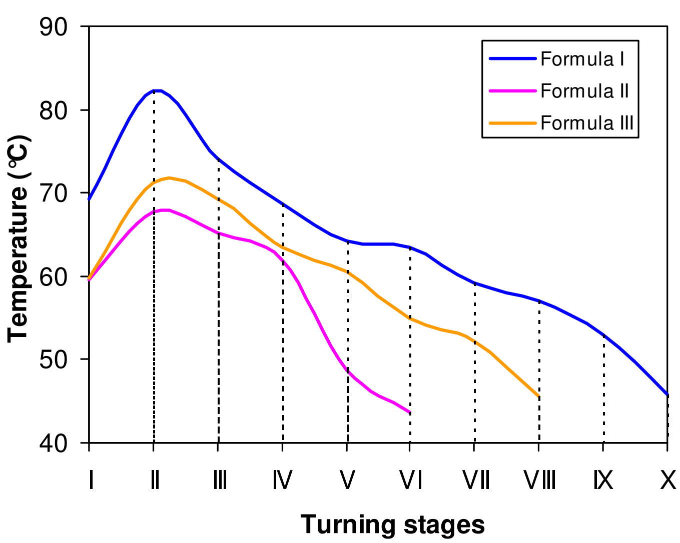

Figure 2. Compost temperature values of formula I, formula II, and formula III.

tea leaves and pigeon manure gave the best mushroom yield followed by a mixture of waste tea leaves and wheat bran, and a mixture of waste tea leaves and chicken manure. The highest mushroom yields were obtained a mixture of waste tea leaves and pigeon manure with the peat of Caykara and perlite mixture as casing material.

We have demonstrated that it is possible to obtain good yields of *A. bisporus* on waste tea leaves based compost formulas. Our mushroom yield values better than those of obtained from wheat straw based compost formulas (Yalinkilic et al., 1994; Colak, 2004). Baysal (1999) reported that mushroom yields of wheat straw based compost formulas and using some locally available peats were between 15.71% to 23.78 % fresh compost weight basis. Our study showed that peat of Caykara gave higher mushroom yields compared to those of other peats.

Conclusions

Three types of compost formulas and locally available casing materials were studied cultivation of *A. bisporus.* Results revealed that all the substrates and activator materials used in different formulations composted within 17-25 days. The compost temperature values for all compost formulas (Figure 2) were at the highest level at the 2nd turning stage after mollasses addition, because of increasing microbial activity of mollases. It is confirmed that the perlite appeared to be an acceptable admentment material for mixing with the peat. The results show that there were significant effect of adding 20% (v/v) perlite to peats on mushroom yield. The most appropriate compost and casing material were found to be waste tea leaves mixed with pigeon manure and peat of Caykara mixed with perlite, respectively.

In conclusion, locally available casing materials are very important factor to obtain maximum and assured yield in the mushroom cultivation (Gulser and Peksen, 2003). In many mushroom growing areas of the world, there are no available sources of peat (Noble and Dobrovin-Pennington, 2005). So, locally available peat sources have vital importance for *A. bisporus* cultivation. Also, it is confirmed that waste tea leaves may be used as a composting material for succesful cultivation of A. *bisporus*.

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