

Full Length Research Paper

Cultivation of *Agaricus bisporus* on wheat straw and waste tea leaves based compost formulas using wheat chaff as activator material

Huseyin Peker^{1*}, Ergun Baysal², Osman Nuri Yigitbasi², Hakan Simsek², Mehmet Colak² and Hilmi Toker²

¹Karadeniz Technical University, Faculty of Forestry, 61080, Trabzon, Turkey.

²Mugla University, Faculty of Technical Education, Kotekli, 48000, Mugla, Turkey.

Accepted 7 December, 2006

This study was designed to determine the pin head formation time and yield values of *Agaricus bisporus* on some casing materials. Composts were prepared basically from wheat straw and waste tea leaves by using wheat chaff as activator substance. Temperatures of the compost formulas were measured during composting at various depths in order to determine the compostability level. Results showed that in both compost types, maximum temperature values were recorded in the second turning stage. Composting was completed in 21 days for both composts. While the fastest pin head formation (12.50 days) was obtained on wheat straw based compost using peat of Bolu (PB) and peat of Agacbasi (PA) (50+50; in volume); waste tea leaves based compost using peat of Caykara (PC) and forest soil (FS) mixture (50+50; in volume) as casing material gave the fastest pin head formation (13.25 days). In terms of yield, a mixture of peat of Bolu and peat of Agacbasi (PA) (50+50; in volume) gave the highest yield for wheat straw based compost, a mixture of peat of Agacbasi and perlite (P) (80+20; involume) had the highest yield for waste tea leaves based compost.

Key words: *Agaricus bisporus*, wheat straw, waste tea leaves, wheat chaff, pin head formation, compost temperature, yield.

INTRODUCTION

All over the world and especially in developing countries, there is a problem of shortage of protein. Producing cultured mushrooms can be suitable solution to this problem. Because of rapid industrialization, the amount of waste materials has increased and utilization of these wastes is very important for government economy and natural balance (Yildiz et al., 2002). Cultivation of edible mushrooms with agricultural residues, such as rice and wheat straw, is a value-added process to convert these materials, which are otherwise considered to be wastes, into human food (Zhang et al., 2002).

A. bisporus is the world's most widely grown culture mushroom species (Coşkuner and Ozdemir, 1997). It

requires two different substrates to form its fruit bodies; i.e the compost in which it grows vegetatively and the poor nutrient casing soil in which the suitable physical, chemical and biological conditions stimulate the initiation process and fruit body production (Segula et al., 1987). Compost for the production of white button mushrooms, *A. bisporus* is, produced from wheat straw, straw-bedded horse manure, chicken manure and gypsum (Straatsma et al., 2000). 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

*Corresponding Authors E-mail: peker100@hotmail.com Tel: +904623772833; Fax: +90-4623253208.

Table 1. Wheat straw and waste tea leaves based composts.

Compost Types	Fresh weight (kg)	Moisture content (%)	Dry weight (kg)	Nitrogen (%)	Nitrogen (kg)
Wheat straw	460.0	15.0	400.0	0.5	2.00
Wheat chaff	147.0	30.0	113.0	1.87	2.11
Ammonium nitrate	20.0	0.0	20.0	26.0	5.20
Urea	8.70	0.0	8.70	44.0	4.75
Molasses	24.0	50.0	16.0	1.3	0.20
Gypsum	24.0	0.0	24.0	0.0	0.0
TOTAL			573.00		14.26
Waste tea leaves	448.0	12.0	400.0	2.3	9.20
Wheat chaff	147.0	30.0	113.0	1.87	2.11
Ammonium nitrate	5.0	0.0	5.0	26	1.30
Urea	2.70	0.0	2.70	44	1.19
Molasses	24.0	50.0	16.0	1.3	0.20
Gypsum	24.0	0.0	24.0	0.0	0.0
TOTAL			560.0		14.00

of the compost stack. However, it was proved long ago by Lambert (1941) that the most productive areas within the current low wide stacks were the regions of the compost within a temperature range of 45 to 55°C. Ross and Harris (1982) found that ammonia disappeared most rapidly in the range of 40-45°C. However, ammonia disappearance was still fairly rapid over the range of 35 to 50°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, many efforts have been made by scientists to develop its 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).

Casing soil has an important role in the cultivation of *A. bisporus*. Peat is generally used and recommended as a good casing medium (Gulser and Peksen, 2003). Because of its unique water holding and structural properties are widely accepted as ideal for the purposes of casing (Colak, 2004; Baysal 1999). But, there are no available sources of peat in many mushroom growing areas (Noble and Dobrovin-Pennington, 2005). This has led to considerable research into possible peat alternatives for casing (Poppe, 2000). Baysal (1999) and Visscher (1988) studied peat and perlite mixture and peat

and chalk or lime mixture as casing material, respectively. Also, Gülser and Peksen (2003) studied the possibility of using tea production waste as a new casing material in *A. bisporus* cultivation. They found that using tea production waste alone as a casing was not acceptable for assured yield when it was compared with peat. But a mixture of tea production waste with peat (1:1; v:v) ratio increased the yield.

This study was aimed to determine pin head formation time and yield values of *A. bisporus* on using some locally available peats and their combination with some secondary casing materials such as perlite, sand, and piece of mosaic. Composts were prepared from wheat straw and waste tea leaves using wheat chaff as activator material. Also, in order to follow the evolution of the composting process, daily temperature measurements were made.

MATERIALS AND METHODS

Preparation of composts

Two composts based wheat straw and waste tea leaves based using wheat chaff as activator material were prepared. Composts used in this study are given in Table 1. The composting of substrates was processed using method of Shandilya (1982). The total outdoor composting process (Phase I) took 21 days for wheat straw and waste tea leaves based composts, respectively. The phase II was processed indoor for 7 days. Percentage nitrogen (N) content of the composts formulas was arranged to 2.5%. Nitrogen contents of compost formulas were determined following equation:

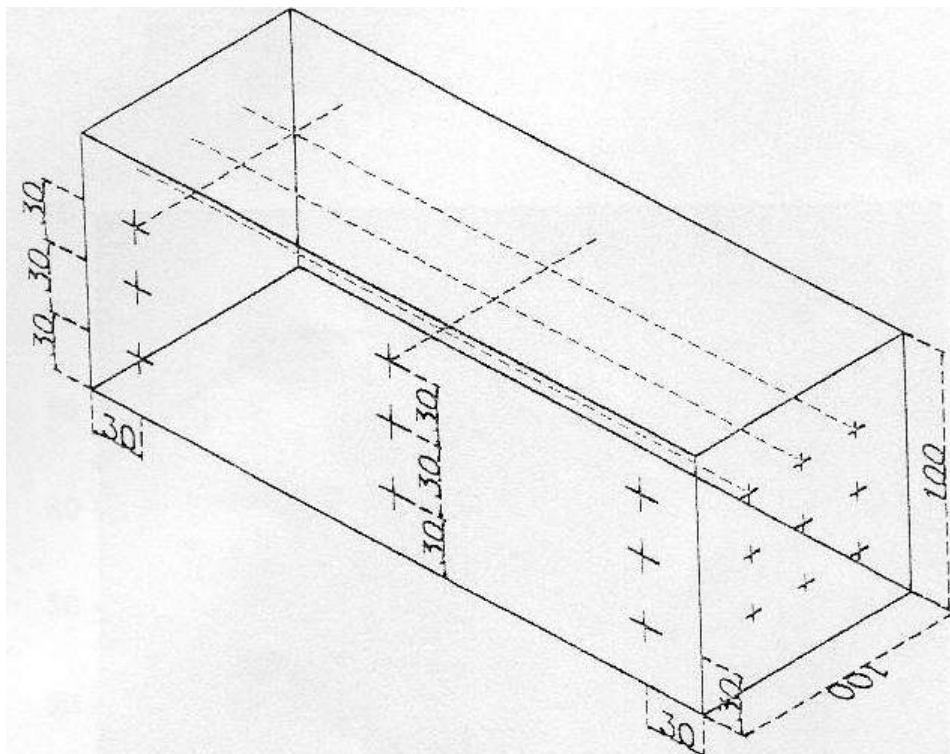


Figure 1. Measuring points of compost temperature.

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

Casing soil

Locally available casing materials such as peat of Bolu (PB), peat of Agacbasi (PA), and peat of Caykara (PC) were used as primary casing materials. Peat of Bolu, peat of Agacbasi, and peat of Caykara were supplied, from Bolu district, Agacbasi district (Sürmene-Trabzon), and Caykara district (Trabzon), in Turkey, respectively. Forest soil (FS) was used as casing material, supplied from Meryemana-Trabzon district, in Turkey. Also, we used some secondary casing materials such as perlite (P), sand (S), and piece of mosaic (PM) with mixture of peat (20:80; v: v) in volume.

Measuring of inner compost temperatures

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 as 30 cm, 60 cm and 90 cm were marked as in the Figure 1. 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. Therefore, totally 432 measures were made for both compost formula. Thus, 27 temperature measurement points were selected in total (Figure 1).

Mushroom cultivation

Composts were 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% relative humidity without ventilation (Hayes and Shandilya, 1977). After mycelia 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. The data concerning pin head formation of *A. bisporus* were recorded as days after casing. Watering after casing was done as suggested for commercial growth (Randle, 1984; Shandilya, 1986). Fresh mushroom yield was calculated using the following equation:

$$\text{Fresh mushroom yield (\%)} = \frac{\text{Weight of fresh mushroom harvested}}{\text{Weight of wet compost used}} \times 100$$

Evaluation of test results

Test results were evaluated by a computerized statistical program composed of analysis of variance and following Duncan tests at the 95% confidence level. Statistical evaluations were made on homogeneity groups (HG), of which different letters reflected statistical significance.

RESULTS

Inner compost temperature degrees

The inner temperature degrees of the wheat straw based compost are given in Table 2. Inner temperature degrees of the compost reached its maximum value of 74.4°C on

Table 2. Temperature values of wheat straw based compost.

Turning stages	Days	Daily temperature values(°C)			Temperature values of turning stages (°C)		
		Mean	Sd*	HG**	Mean	Sd	HG
I	1	68.0	2.96	hi	66.2	2.42	d
	2	68.6	2.86	i			
	3	67.2	2.13	hi			
	4	64.4	1.52	gh			
	5	63.0	1.69	fg			
II	6	69.4	1.33	i	70.8	2.44	e
	7	74.4	3.23	j			
	8	70.1	2.33	i			
III	9	69.2	2.33	i	67.6	0.63	d
	10	67.2	1.70	hi			
IV	11	68.1	2.24	hi	56.7	0.77	c
	12	57.3	2.62	de			
V	13	56.7	1.79	de	57.1	2.05	c
	14	55.7	1.64	de			
VI	15	58.6	1.91	e	57.6	2.96	c
	16	59.7	1.24	ef			
VII	17	55.5	1.96	cd	52.6	1.55	b
	18	53.7	2.10	bcd			
VIII	19	51.5	1.39	bc	47.6	3.39	a
	20	50.0	1.10	b			
	21	45.2	4.01	a			

Standart deviation
Homogeneity groups

the 7th day of the composting process. When turning stages are considered, the highest temperature degrees of all compost formulas were measured at the second turning stage (70.8°C). This was followed respectively by III, I, VI, V, VII, and VIII turning stages. There were significant differences between the second turning stage and other turning stages. The highest temperatures were obtained in the second turning stage is believed to be due to temperature increasing effect of molasses added to the compost. Inner temperature degrees of the composts raised to a peak level at the 1st and 2nd turning stages followed by a gradual decrease observed. It can be claimed that this is because of the fact that activator substances were not added after the 9th day and no compression was performed during the other turning stages. The composting process was completed in 21 days, and the temperature value when the composting was completed was 47.2 °C.

The inner temperature degrees of the waste tea leaves based compost are given in Table 3. The inner temperature degrees of the compost reached its maximum value of 69.7°C on the 9th day of the composting. When turning stages are considered, the highest temperature was obtained in the second turning stage (67.9°C). But no significant difference was observed between II and I

turning stages. Inner temperature degrees of the composts raised to a peak level at the 1st and 2nd turning stages followed by a gradual decrease observed. The composting was completed in 21 days, and the temperature value when the composting was completed was 42.8°C. The inner temperature degrees of the turning stages for both composts are given in Figure 2.

Pin head formation time

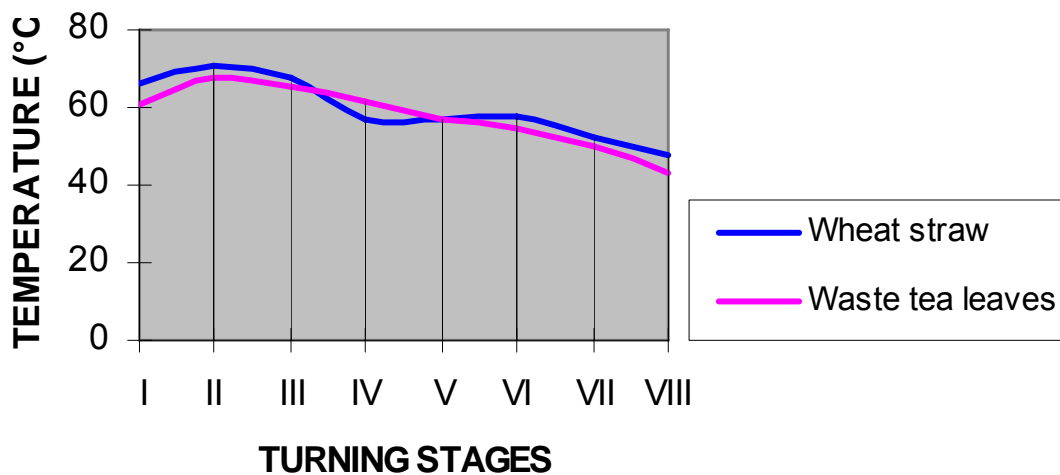
Time periods of pin head formation on wheat straw based compost are given in Table 4. The most rapid pine head formation took place in 12.50 days with peat of Bolu and peat of Agacbasi mixture (50+50; in volume). The latest pin head formation time took place in 19.50 days with a mixture of forest soil and piece of mosaic (80+20; in volume). The sand adversely affected the pin head formation time. The reason of this adverse effect may be due to the high ratio of sand in the mixture (Baysal, 1999). Although when peats were used in combination with each other, the period of pin head formation shortened, but no significant difference was found between their individual use and their use in combination. The most suitability of casing materials in terms of pin

Table 3. Temperature values of waste tea leaves based compost.

Turning stages	Days	Daily temperature values(°C)			Temperature values of turning stages (°C)		
		Mean	Sd [*]	HG ^{**}	Mean	Sd	HG
I	1	55.7	2.48	de	60.8	3.45	d
	2	59.2	2.01	fg			
	3	62.2	2.50	ghi			
	4	63.0	2.31	hij			
	5	64.3	2.88	ijkl			
II	6	66.3	1.49	jklm	67.9	1.39	e
	7	67.8	2.21	lm			
	8	68.0	1.83	m			
	9	69.7	2.11	m			
III	10	66.8	1.50	klm	65.4	1.90	e
	11	64.1	1.40	hijk			
IV	12	62.8	2.10	hij	61.7	1.55	d
	13	60.6	1.88	fgh			
V	14	58.6	1.51	ef	57.0	2.26	c
	15	55.4	1.66	de			
VI	16	54.8	1.24	d	54.5	0.42	c
	17	54.2	1.36	d			
VII	18	50.8	2.84	c	49.8	1.34	b
	19	48.9	1.66	c			
VIII	20	44.6	1.21	b	42.8	2.47	a
	21	41.1	1.88	a			

*Standart deviation

**Homogeneity groups

**Figure 2.** Temperature values of both composts in turning stages.

head formation were group IV, group III, group II, group V, and group VI. But, no significant differences were observed for those casing groups.

Time periods of pin head formation on waste tea leaves based compost are given in Table 5. The most rapid pin head formation took place in 13.25 days with peat of Bolu and peat of Agacbasi mixture (50+50; in volume).

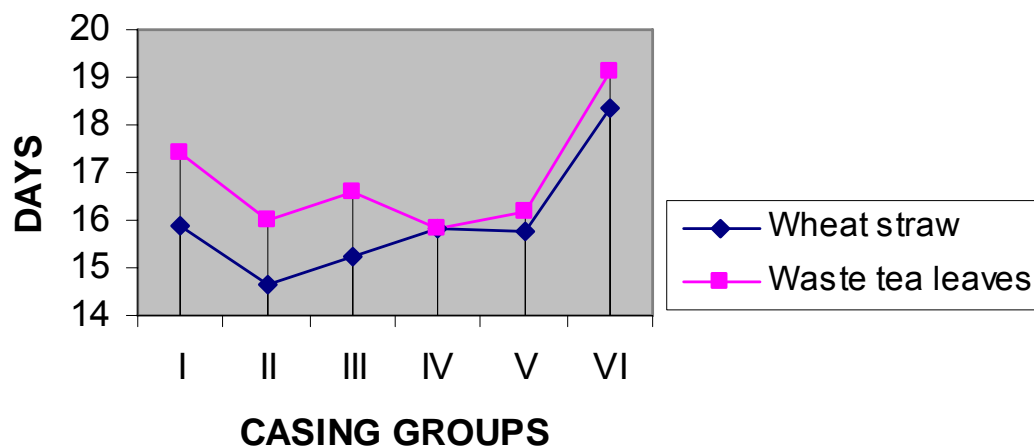
Table 4. Pin head formation time of *A. bisporus* on wheat straw based compost.

Casing groups	Casing material	Mixture Ratio* (%)	Pin head formation time (days)			Pin head formation time (days)		
			Mean	Sd**	HG***	Mean	Sd	HG
I	PB	100	15.50	0.57	bc	15.87	1.98	a
	PA	100	15.00	0.81	cde			
	PC	100	14.00	0.00	cdef			
	FS	100	18.75	2.06	j			
II	PB+PA	50+50	12.50	0.57	a	14.66	2.11	a
	PB+PC	50+50	13.25	0.50	ab			
	PB+FS	50+50	18.00	0.00	ij			
	PA+PC	50+50	13.25	1.50	efg			
	PA+FS	50+50	16.25	1.50	efg			
	PC+FS	50+50	14.75	0.50	bcd			
III	PB+P	80+20	16.00	0.57	bcd	15.25	1.30	a
	PB+S	80+20	16.00	0.81	efg			
	PB+PM	80+20	13.75	0.95	efg			
IV	PA+P	80+20	14.50	1.73	cde	15.83	1.89	a
	PA+S	80+20	18.00	0.00	ghi			
	PA+PM	80+20	15.00	0.00	bc			
V	PC+P	80+20	15.75	0.50	defg	15.75	1.25	a
	PC+S	80+20	17.00	0.00	efg			
	PC+PM	80+20	14.50	1.00	bcd			
VI	FS+P	80+20	18.50	1.73	ghi	18.33	1.01	b
	FS+S	80+20	19.25	1.50	hij			
	FS+PM	80+20	19.50	1.00	hij			

*In volume

**Standart deviation

***Homogeneity groups

**Figure 3.** Pin head formation time of *A. bisporus* on casing groups.

Forest soil gave the worst results for pin head formation time. No significant differences were found between their individual use of peats and their use in combination with each other with regards to period of pin head formation. The worst results with regards to the period of pin head

formation were produced by group IV casing materials. But, no significant differences were found between group VI and other casing groups. The pin head formation times for both composts on casing groups are given in Figure 3.

Table 5. Pin head formation time of *A. bisporus* on waste tea leaves based compost.

Casing groups	Casing material	Mixture Ratio* (%)	Primordium Formation Time (day)			Primordium Formation Time (day)		
			Mean	Sd**	HG***	Mean	Sd	HG
I	PB	100	17.50	1.73	fgh	17.43	3.60	a
	PA	100	14.75	0.50	abc			
	PC	100	15.00	0.81	abcd			
	FS	100	22.50	1.29	j			
II	PB+PA	50+50	13.75	0.50	ab	16.00	2.24	a
	PB+PC	50+50	17.25	0.50	fgh			
	PB+FS	50+50	19.00	1.41	hi			
	PA+PC	50+50	15.50	1.73	cdef			
	PA+FS	50+50	17.25	1.89	efgh			
	PC+FS	50+50	13.25	0.50	a			
III	PB+P	80+20	16.50	0.57	defg	16.58	1.38	a
	PB+S	80+20	18.00	0.00	gh			
	PB+PM	80+20	15.25	0.95	bcde			
IV	PA+P	80+20	14.50	1.73	abc	15.83	1.89	a
	PA+S	80+20	18.00	1.41	gh			
	PA+PM	80+20	15.00	0.81	abcd			
V	PC+P	80+20	17.25	1.50	efgh	16.16	2.32	a
	PC+S	80+20	17.75	2.06	cdef			
	PC+PM	80+20	13.50	1.00	abc			
VI	FS+P	80+20	17.50	0.57	efgh	19.09	1.43	a
	FS+S	80+20	20.25	1.70	i			
	FS+PM	80+20	19.50	0.57	i			

*In volume

**Standart deviation

***Homogeneity groups

Mushroom yields

Average mushroom yields of the four flushes from the wheat straw based compost are given in Table 6. Peat of Bolu and peat of Agacbasi (50+50) mixture gave the highest yield (22.75%). The lowest yield (8.21%) was obtained by a mixture of forest soil and sand (80+20). No significant difference was observed in the yield values when the peats were used in combination with each other compared to their individual use. Among the casing groups, the highest yield value (1296 g) was recorded in the group V. This group was followed by group II, group III, group IV, and group I. But, there were no statistically significant differences between group V and these casing groups. Group VI, as in the other features, with regards to the yield gave the worst results.

Average mushroom yields of the four flushes from the waste tea leaves based compost are given in Table 7. While a mixture of peat of Agacbasi and perlite gave the highest yield (20.87%), forest soil gave the worst results in terms of yield. Secondary casing materials such as perlite yielded considerable improvements in average mushroom yield of mixtures with peats. No significant differences were observed in the yield values when the

peats were used in combination with each other compared to their individual use. Among the casing material groups, the highest yield value was obtained in the group IV casing materials. But, no significant difference was observed between group IV and group V. Yield values of these groups is significantly higher than other casing groups. Group VI as in the other features, with regards to the yield produced the worst results. Average mushroom yields for both composts on casing groups are given in Figure 4.

DISCUSSION

In the present study, two types of composts were prepared and locally available peats and some secondary casing materials were used to grow *A. bisporus*. Results revealed that all the organic ingredients used in different formulations composted well within 21 days for both composts. As a result of microbial activities within composts, measured inner temperatures of all compost formulas reached to the highest level at the 2nd turning stage after molasses addition. It might be probably due to addition of molasses at the 6th day of composting process. Increased temperature at this stage is an indicator

Table 6. Average mushroom yield of *A. bisporus* on wheat straw based compost.

Casing groups	Casing materials	Mixture Ratio ⁺ (%)	Yield ^{**} (gr)	Sd ^{***}	Yield (%)	HG ^{****}	Yield (gr)	Sd	HG
I	PB	100	1359.5	150.1	19.41	ghı	1187	319	b
	PA	100	1355.2	119.5	19.35	hij			
	PC	100	1325.7	196.0	18.93	efgh			
	FS	100	709.5	121.5	10.13	a			
II	PB+PA	50+50	1593.7	150.9	22.75	j	1296	181	b
	PB+PC	50+50	1154.5	166.8	16.48	bcdefg			
	PB+FS	50+50	1419.5	149.7	20.27	hij			
	PA+PC	50+50	1298.5	101.4	18.29	defgh			
	PA+FS	50+50	1124.7	112.5	16.05	bcde			
	PC+FS	50+50	1190.5	107.2	17.00	cdefg			
III	PB+P	80+20	1411.0	32.0	20.16	hij	1235	203	b
	PB+S	80+20	1012.2	96.4	14.46	bc			
	PB+PM	80+20	1283.7	157.5	18.34	defgh			
IV	PA+P	80+20	1478.5	105.2	21.11	fghı	1208	252	b
	PA+S	80+20	977.0	96.1	13.96	b			
	PA+PM	80+20	1171.7	143.4	16.72	bcdefg			
V	PC+P	80+20	1548.0	76.4	22.11	ij	1331	192	b
	PC+S	80+20	1182.2	173.9	16.89	bcdefg			
	PC+PM	80+20	1264.0	53.0	18.06	bcdef			
VI	FS+P	80+20	1102.5	37.5	15.74	bcd	801	276	a
	FS+S	80+20	559.5	50.2	7.98	a			
	FS+PM	80+20	744.7	228.2	10.62	a			

*In volume

**Results reflect observations of four plastic bags and composts were filled into plastic bags as 7kg weights basis

***Standart deviation

****Homogeneity groups

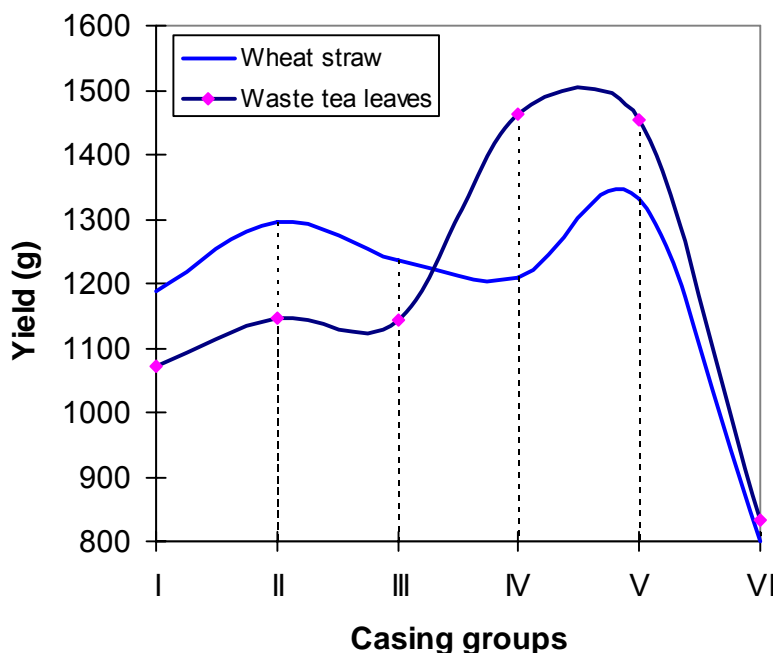


Figure 4. Average mushroom yield of *A. bisporus* on casing groups.

Table 7. Average mushroom yield of *A. bisporus* on waste tea leaves based compost.

Casing groups	Casing materials	Mixture Ratio* (%)	Yield** (gr)	Sd***	Yield(%)	HG****	Yield (gr)	Sd	HG
I	PB	100	1065.0	94.0	15.21	c	1072	416	b
	PA	100	1509.0	122.0	21.55	gh			
	PC	100	1194.0	144.2	17.05	cdef			
	FS	100	522.0	139.5	7.45	a			
II	PB+PA	50+50	1217.0	164.9	17.39	cde	1145	214	b
	PB+PC	50+50	1242.0	116.7	17.74	cdef			
	PB+FS	50+50	722.2	138.2	10.31	ab			
	PA+PC	50+50	1301.0	157.3	18.58	cd			
	PA+FS	50+50	1141.7	95.0	16.30	c			
	PC+FS	50+50	1252.7	209.0	17.88	cdef			
III	PB+P	80+20	1436.7	120.0	20.51	efgh	1143	525	b
	PB+S	80+20	536.2	114.3	7.66	a			
	PB+PM	80+20	986.6	85.6	20.81	fgh			
IV	PA+P	80+20	1648.0	180.2	23.54	h	1464	240	c
	PA+S	80+20	1192.2	172.9	17.03	cd			
	PA+PM	80+20	1552.5	173.7	22.17	gh			
V	PC+P	80+20	1573.0	161.3	22.47	gh	1455	104	c
	PC+S	80+20	1420.5	135.4	20.28	defgh			
	PC+PM	80+20	1407.7	81.2	20.10	defg			
VI	FS+P	80+20	899.7	111.8	12.84	b	834	64	a
	FS+S	80+20	832.2	117.5	11.88	b			
	FS+PM	80+20	771.5	103.4	11.01	b			

*In volume

**Results reflect observations of four plastic bags and composts were filled into

***plastic bags as 7kg weights basis

****Standart deviation

*****Homogeneity groups

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.

When peats were used in combination with each other, the period of pin head formation shortened. But, no significant differences were observed in the yield values when the peats were used in combination with each other compared to their individual use. The sand adversely affected the pin head formation time and mushroom yield. It may be due to the high ratio of sand (20%) in the mixture. Addition of perlite to peat significantly increased mushroom yield. This is in good agreement with previous studies in which perlite was reported to be a good casing material used with mixture of peat (Baysal, 1999; Colak, 2004; Yalinkilic et al., 1994). Forest soil gave the worst results in terms of pin head formation time and mushroom yield for both composts.

REFERENCES

- Baysal E (1999). Utilization possibilities of waste tea leaves in the cultivation of *Agaricus bisporus* (Lange) Sing., P.h.D. Thesis, Karadeniz Technical University, Trabzon, Turkey, p. 157.
- Bech K (1973). Preparing for productive commercial compost as a selective growing medium for *Agaricus bisporus* (Lange) Singer. *Mushroom Sci.* 10 (2): 77-83.
- Colak M (2004). Temperature profiles of *Agaricus bisporus* in composting stages and effects of different composts formulas and casing materials on yield. *Afr. J. Biotechnol.* 3(9): 456-462.
- Coşkuner Y, Özdemir Y (1997). Effects of canning processes on the elements content of cultivated mushrooms (*Agaricus bisporus*). *Food Chem.* 60(4): 559-562.
- Gulser C, Peksen A (2003). Using tea waste as a new casing material in Mushroom (*Agaricus bisporus* (L.)Sing.) Cultivation. *Biores. Technol.* 88: 153-156
- Lambert EB (1929). Normal mushrooms from artificial manure. *Science* 70: 126-128.
- Lambert EB (1941). Studies on the preparation of mushroom compost. *J. Agric. Res.* pp. 415-422.
- Noble R, Dobrovin-Pennington A (2005). Partial substitution of peat in mushroom casing with fine particle coal tailings. *Sci. Hortic.* 104: 351-367.
- Poppe J (2000). Use of agricultural waste materials in the cultivation of mushrooms. In: Van Griensven LJ (Ed.), *Science and Cultivation of Edible Fungi*. Balkema, Rotterdam, pp. 3-23.
- Randle PH, Hayes WA (1972). Progress in experimentation on the efficiency of composting and compost. *Mushroom Sci.* 8: 789-795.
- Randle PE (1984). Supplementation of mushrooms composts: A review *Mush. J.* 151: 241-269.
- Ross RC, Harris PJ (1982). Some factors involved in faz II of mushroom compost preparation. *Sci. Hortic.* 19: 223-229.
- Ross RC, Harris PJ (1983). The signigicance of thermophilic fungi in

- mushroom compost preparation. *Sci. Hortic.* 20: 61-70.
- Segula M, Levanon D, Danai O, Henis Y (1987). Nutritional supplementation to the casing soil: Ecological aspects and mushroom production. *Mushroom Science XII Proceedings of the Twelfth International Congress on the Science and Cultivation of Edible Fungi*, 417-426.
- Shandilya TR (1979). Different compost substrates used in India. *Mush. J.* 78: 262-264.
- Shandilya TR (1982). Composting betters mushroom yield. *Indian Hort.* 27 (1): 13-18.
- Shandilya TR (1986). Effect of differently pasteurized composts on the yield of *Agaricus bisporus* Ind. *J. Plant. Pathol.* 4(1): 89-90.
- Sinden JW, Hauser E (1953). The nature of composting process and its relation to short composting. *Mush. Sci.* 2: 123-130.
- Straatsma G, Gerrits Jan.PG, Thissen Jac TNM, Amsing Jos GM, Loeffen H, Van Griensven Leo JLD (2000). Adjustment of the composting process for mushroom cultivation based on initial substrate compos. *Biores. Technol.* 72: 67-74.
- Tewari RP, Sohi HS (1976). Studies on the use of paddy straw and maize stalks as substitutes for wheat straw to prepare synthetic compost for cultivation of European mushroom *Agaricus bisporus*. *Ind. J. Mushrooms* 2 (2): 18-20.
- Visscher HR (1988). Casing soil. In: Van Griensven, L.J.L.D. (E.d.), *The cultivation of mushrooms*. Darlington Mushroom Laboratories Ltd., Rustington, Sussex, UK, pp. 73-88.
- Yildiz S, Yildiz UC, Gezer ED, Temiz A (2002). Some lignocellulosic wastes used as raw material in cultivation of the *Pleurotus ostreatus* culture mushroom. *Process Biochem.* 38: 302-306.
- Zhang Ruihong Li X, Fadel JG (2002). Oyster mushroom cultivation with rice and wheat straw. *Biores. Technol.* 82: 277-284.