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Full Length Research Paper

Cultivation of *Agaricus bisporus* on wheat straw and waste tea leaves based composts using poplar leaves as activator material

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This study was carried out to determine pin head formation time and mushroom yield of *Agaricus bisporus* on some casing materials. Composts were prepared basically from wheat straw and waste tea leaves using poplar leaves as activator material. In this study, moreover, in order to follow the evolution of the composting process, daily temperature measurements were taken. According to the results of the study, in both compost types, maximum temperature values were observed in the second turning stage. While in the first and second turning stages, inner-pile temperature of the compost was in a tendency of exhibiting steady increase, they are prone to decrease in the following turning stages. In both composts, the period of composting has finished in 19 days. While the fastest pin head formation (13 days) was obtained on wheat straw based compost using peat of Caykara (PC) and forest soil (FS) (50+50; in volume); waste tea leaves based compost using peat of Bolu (PB) and peat of Caykara (PC) mixture (50+50; in volume) as casing material gave the fastest pin head formation (13.30 days). While, a mixture of peat of Agacbasi (PA) and perlite (P) gave the highest yield for wheat straw based compost, peat of Bolu shows the highest yield for waste tea leaves based compost.

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

INTRODUCTION

Agaricus 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 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). 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).

Due to scarcity of hourse 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 on their availability (Shandilya, 1979; Tewari and Sohi, 1976; Lambert, 1929; Sinden and Hauser, 1953).

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. 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.

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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
Poplar leaves	175.0	55.0	113.0	1.3	1.46
Ammonium nitrate	21.0	0.0	21.0	26.0	5.46
Urea	13.0	0.0	13.0	44.0	5.72
Molasses	24.0	50.0	16.0	1.3	0.20
Gypsum	24.0	0.0	24.0	0.0	0.0
TOTAL			**587.0**		**14.84**
Waste tea leaves	448.0	12.0	400.0	2.3	9.20
Poplar leaves	175.0	55.0	113.0	1.3	1.46
Ammonium nitrate	6.0	0.0	6.0	26	1.69
Urea	3.0	0.0	3.0	44	1.32
Molasses	24.0	50.0	16.0	1.3	0.20
Gypsum	24.0	0.0	24.0	0.0	0.0
TOTAL			**562.0**		**13.93**

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).

The casing layer is an essential part of the total substrate in the artificial culture of *A. bisporus*. Although many different materials may adequately function as a casing layer, peat is commonly used and recommended as a good casing in mushroom cultivation (Gülser and Peksen, 2003). Because of its unique water holding and structural properties, they are widely accepted as ideal for the purposes of casing. Casting, infact, has a neutral pH and because of its contention in organic matter and granular structure, strays porous even after a succession of watering, holds 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).

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 based using poplar leaves as activator material. Also, in order to follow the evolution of the composting process, daily temperature measurements were made.

MATERIALS AND METHODS

Two composts based wheat straw and waste tea leaves using poplar leaves as activator material were studied. 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 19 days for wheat straw and waste tea leaves based composts. 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:

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

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 (Surmene-Trabzon), and Caykara district (Trabzon), in Turkey, respectively. Forest soil (FS) was used as casing material, supplied from Meryemana-Trabzon district, in Turkey. Also, 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 were used.

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. 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℃ with a minimum supply of

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	70.1	3.40	j	64.2	3.65	d
	2	65.6	2.78	fghıj			
	3	62.6	1.71	defghı			
	4	61.4	2.30	defg			
	5	61.7	1.95	defgh			
II	6	62.9	3.39	efghı	65.9	2.04	d
	7	67.5	4.02	ıj			
	8	66.7	3.83	hıj			
	9	66.5	3.80	ghıj			
III	10	58.8	3.51	de	60.1	1.83	c
	11	61.4	2.02	defg			
IV	12	57.5	3.42	d	60.0	3.53	c
	13	62.5	2.80	defghı			
V	14	60.7	1.31	def	60.3	0.49	c
	15	60.0	1.56	de			
VI	16	52.9	2.32	c	48.6	6.01	b
	17	44.4	2.04	b			
VII	18	42.6	1.13	ab	41.0	2.19	a
	19	39.5	0.60	a			

*Standart deviation
**Homogeneity groups

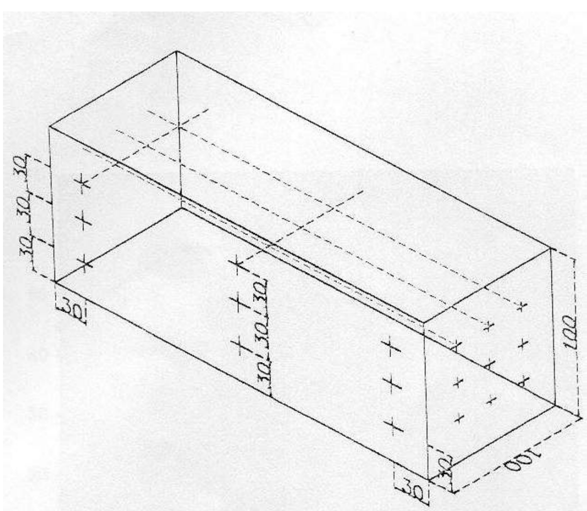

Figure 1. Measuring points of compost temperature.

fresh air. Spawning room arranged to 25℃ 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℃, with ventilation, for pin head 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 temperatures

Inner-pile temperature values for the compost which is a mixture of wheat straw and poplar leaves are given in Table 2. Inner-pile temperature of the compost reached its maximum value of 67.5℃ on the seventh day of the composting process. When turning stages are considered, the highest temperature was obtained in the second turning stage (65.9℃). This was followed respectively by I. turning, V turning, III. turning, IV. turning, and VI. turn-

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

Turning stages	Day	Daily temperature values			Temperatures values of turning		
		Mean	Sd*	HG**	Mean	Sd	HG
I	1	62.3	2.09	de	63.6	1.33	de
	2	62.7	1.81	de			
	3	65.7	1.87	efg			
	4	64.1	2.05	def			
	5	63.6	2.41	def			
II	6	67.5	1.76	fgh	68.2	1.51	f
	7	66.8	1.65	fgh			
	8	68.2	1.27	gh			
	9	70.3	1.56	h			
III	10	64.3	1.92	defg	64.8	0.70	e
	11	65.3	1.46	defg			
IV	12	62.6	1.31	de	62.1	0.70	d
	13	61.8	1.31	d			
V	14	56.2	2.50	c	55.0	1.69	c
	15	53.8	2.41	c			
VI	16	49.4	3.13	b	47.0	2.33	b
	17	46.1	2.41	ab			
VII	18	44.3	3.11	a	43.7	0.77	a
	19	43.2	2.18	a			

*Standart deviation
**Homogeneity groups

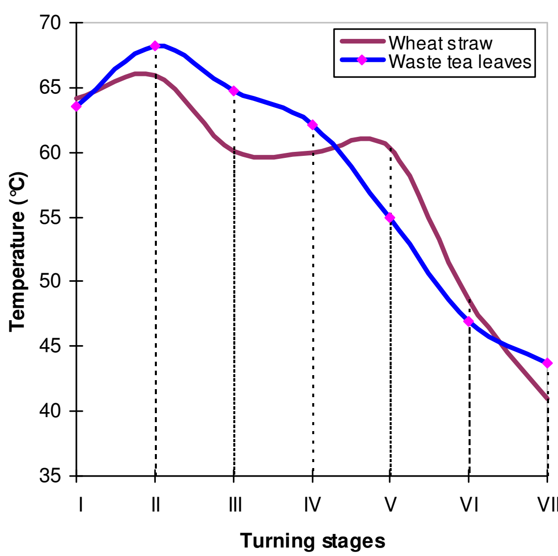

Figure 2. Temperature values of both composts in turning stages.

ing stages. No statistically significant difference was observed between II. turning and I. turning stages. In the same token, no significant difference was observed among III. turning, IV. turning, and V. turning stages. The highest temperature was obtained in the second turning stage is believed to be due to temperature increasing effect of molasses added to the compost. While the inner-pile temperature of the compost was in a steady increase in the I. turning and II. turning stages, it decreased in the following turning stages. 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 19 days, and the temperature value where the composting was completed was 39.5°C.
Inner-pile temperature values for the compost which is a mixture of waste tea leaves and poplar leaves are given in Table 3. Inner-pile temperature of the compost reached its maximum value of 70.3°C on the 9th day of the composting. When turning stages are considered, the highest temperature was obtained in the second turning stage (68.2°C). While the inner-pile temperature of the compost was in a steady increase in the I. turning and II. turning stages, it decreased in the subsequent turning stages. The composting was completed in 19 days, and the temperature value where the composting was completed was 43.2°C. The temperature values 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. Peat of Caykara and forest

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

Casing groups	Casing materials	Mixture ratio* (%)	Pin head formation time (days)			Pin head formation time (days)		
			Mean	Sd**	HG***	Mean	Sd	HG
I	PB	100	13.75	0.95	abc	16.13	2.74	a
	PA	100	14.75	0.50	bcde			
	PC	100	16.00	0.00	bcd			
	FS	100	20.00	0.00	k			
II	PB+PA	50+50	17.00	0.81	a	16.00	2.50	a
	PB+PC	50+50	15.25	1.25	abc			
	PB+FS	50+50	19.25	2.62	j			
	PA+PC	50+50	13.50	1.00	bcd			
	PA+FS	50+50	18.00	0.00	ıj			
	PC+FS	50+50	13.00	1.73	bcd			
III	PB+P	80+20	15.50	1.00	ab	15.90	2.61	a
	PB+S	80+20	18.25	0.95	ıj			
	PB+PM	80+20	14.00	0.00	bc			
IV	PA+P	80+20	14.75	1.25	defg	15.00	1.45	a
	PA+S	80+20	16.25	0.50	fgh			
	PA+PM	80+20	14.25	0.50	cdef			
V	PC+P	80+20	17.25	0.50	hı	16.00	1.56	a
	PC+S	80+20	16.50	1.91	efgh			
	PC+PM	80+20	14.25	0.50	bcd			
VI	FS+P	80+20	18.75	0.95	j	19.33	0.80	b
	FS+S	80+20	20.25	1.50	ghı			
	FS+PM	80+20	19.00	0.50	ıj			

*In volume
*Standart deviation
**Homogeneity groups

soil mixture (50+50; in volume) yielded the most suitable casing material mixture with average of 13.00 days. This casing mixture is then followed by peat of Bolu and peat of Caykara mixture (50+50; in volume) with equal average. A mixture of forest soil and sand (80+20; in volume) used in the experiment was the casing material yielded worst results (20.25 days). 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 head formation are group IV, group III, group II, group V, and group VI, respectively. 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. Peat of Bolu and peat of Caykara (50+50) yielded the most suitable casing material mixture with average 13.00 days. 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 VI 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.

Mushroom yields

Average mushroom yield of the four flushes from the wheat straw based compost is given in Table 6. Peat of Agacbasi and perlite (80+20) mixture showed the highest yield (22.91%). The lowest yield (8.21%) was obtained by forest soil. 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 (1302 g) was obtained in the group II. This group was followed by group IV and group III, between which there are no statistically significant differences. Group VI, as in the other features, with regards to the yield produced the worst

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

Casing groups	Casing materials	Mixture ratio* (%)	Pin head formation time (days)			Pin head formation time (days)		
			Mean	Sd**	HG***	Mean	Sd	HG
I	PB	100	17.00	0.00	efg	17.00	2.83	a
	PA	100	14.75	0.50	abc			
	PC	100	15.25	0.50	bcd			
	FS	100	21.00	2.06	kı			
II	PB+PA	50+50	13.50	1.29	a	15.75	2.12	a
	PB+PC	50+50	13.30	1.29	ab			
	PB+FS	50+50	18.50	1.29	jkl			
	PA+PC	50+50	15.00	1.15	abcd			
	PA+FS	50+50	17.75	0.95	ghı			
	PC+FS	50+50	16.25	1.50	def			
III	PB+P	80+20	16.25	1.50	cde	16.00	0.90	a
	PB+S	80+20	16.75	1.25	efg			
	PB+PM	80+20	15.00	1.41	abcd			
IV	PA+P	80+20	14.50	0.57	abc	15.50	2.18	a
	PA+S	80+20	18.00	0.00	hıj			
	PA+PM	80+20	14.00	1.41	ab			
V	PC+P	80+20	18.50	0.53	ıjk	16.83	1.63	a
	PC+S	80+20	18.50	0.53	bcd			
	PC+PM	80+20	15.25	0.50	ab			
VI	FS+P	80+20	20.50	1.29	kl	19.75	1.52	b
	FS+S	80+20	20.75	2.75	l			
	FS+PM	80+20	18.00	1.41	jkl			

*In volume
**Standart deviation
***Homogeneity groups

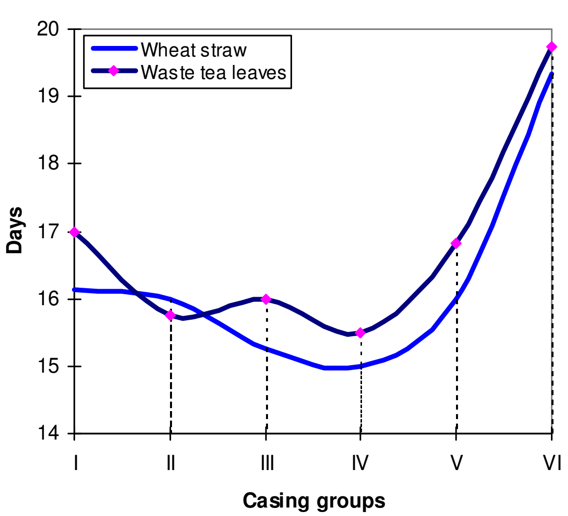

Figure 3. Pin head formation time of *A. bisporus* on casing groups.

results. Secondary casing materials such as P and PM affected the yield values in a positive way.

Average mushroom yields of the four flushes from the waste tea leaves based compost are given in Table 7. While peat of Bolu gave the highest yield (20.87%), forest soil gave the worst results in terms of yield. Secondary casing materials such as P and PM yielded considerable improvements in average mushroom yield of mixtures with forest soil. 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 (1287 g) was obtained in the group V casing materials. No significant difference was observed among group II, group III, group, IV group. 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

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 PA PC FS	100 100 100 100	1121.0 1188.5 1181.0 577.5	113.5 106.3 57.6 182.6	16.01 16.97 17.85 8.21	efg ghı def a	1033	310	ab
II	PB+PA PB+PC PB+FS PA+PC PA+FS PC+FS	50+50 50+50 50+50 50+50 50+50 50+50	1351.0 1364.5 1128.0 1251.2 1414.5 1306.5	61.9 172.3 186.8 162.8 116.3 219.6	19.30 19.48 16.11 17.87 20.20 18.65	hıj ıj efg ghıj jk hıj	1302	101	d
III	PB+P PB+S PB+PM	80+20 80+20 80+20	1245.0 952.0 1088.0	91.2 119.9 86.3	17.78 13.60 16.97	ghıj cde ıj	1128	155	cd
IV	PA+P PA+S PA+PM	80+20 80+20 80+20	1604.2 786.2 1074.0	94.9 99.3 132.9	22.91 11.22 15.54	k bc ef	1159	413	cd
V	PC+P PC+S PC+PM	80+20 80+20 80+20	1242.0 947.2 1029.5	116.1 97.6 78.1	17.74 13.52 14.70	ghıj cde def	1072	152	bc
VI	FS+P FS+S FS+PM	80+20 80+20 80+20	966.0 845.5 693.0	48.0 97.9 118.6	13.07 12.07 9.90	cde bcd ab	834	156	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

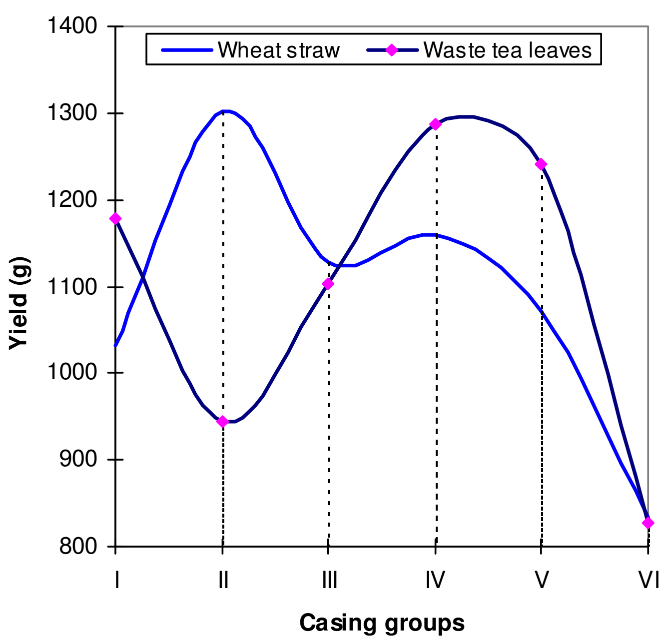

Figure 4. Average mushroom yield of *A.bisporus* on casing groups.

formulations composted well with in 19 days for both composts. As a result of microbial activities within composts, inner temperatures of all compost formulas reached to the highest level at the 2nd turning stage. It might be probably due to addition of molasses 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).

When peats were used in combination with each other, the period of pin head formation shortened. The sand adversely affected the pin head formation. The reason of this adverse effect may be due to the high ratio of sand (20%) in the mixture. Secondary casing materials such as P and PM affected the yield values in a positive way. 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). Colak (2004) reported that a mixture of peat with perlite in 80:20 (v/v) and 70: 30 (v/v) ratios provided

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	1461.0	145.3	20.87	hı	1178	314	ab
	PA	100	1327.5	71.1	18.96	efg			
	PC	100	1187.0	267.3	16.96	de			
	FS	100	737.2	48.3	10.53	ab			
II	PB+PA	50+50	1176.5	139.4	16.80	de	945	217	ab
	PB+PC	50+50	865.5	71.3	12.36	bc			
	PB+FS	50+50	588.5	113.2	8.4	a			
	PA+PC	50+50	1024.2	85.2	14.63	cd			
	PA+FS	50+50	878.2	118.7	12.54	bc			
	PC+FS	50+50	1114.2	146.9	20.57	de			
III	PB+P	80+20	1191.0	161.4	17.01	de	1103	207	ab
	PB+S	80+20	874.0	82.5	12.48	bc			
	PB+PM	80+20	1245.5	86.7	17.79	ef			
IV	PA+P	80+20	1452.7	82.4	20.74	hı	1287	243	c
	PA+S	80+20	1008.7	97.6	14.40	cd			
	PA+PM	80+20	1403.7	119.1	20.04	ghı			
V	PC+P	80+20	1252.7	253.9	17.88	ı	1241	37	c
	PC+S	80+20	1200.7	144.7	17.14	def			
	PC+PM	80+20	1272.5	25.4	18.18	efg			
VI	FS+P	80+20	883.5	111.5	12.61	bc	828	141	a
	FS+S	80+20	668.7	141.2	9.54	a			
	FS+PM	80+20	934.7	97.2	13.34	bc			

*In volume
**Results reflect observations of four plastic bags and composts were filled into plastic bags as 7kg weights basis
***Standart deviation
****Homogeneity groups

higher yield than sole peat using a casing material. Forest soil gave the worst results in terms of average mushroom yields for two compost types.

REFERENCES

Baysal E (1999). Utilization possibilities of waste tea leaves in the cultivation of *Agaricus bisporus* (Lange) Sing., Ph. D. Thesis, Karadeniz Technical University, Trabzon, Turkey. pp: 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. Vol. 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.

Eger G (1972). Experiments and comments on the action of bacteria on sphorophore initation in *Agaricus bisporus*. Mush. Sci. 8: 719-725.

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.

Hayes WA, Randle PE, Last FT (1969). The nature of the microbial stimulus affecting sporophore formation in *Agaricus bisporus* (Lange) Sing. Ann. Appl. Biol. 64: 177-187.

Hayes WA, Shandilya TR (1977). Casing soil and compost substrates used in the artifical culture of *Agaricus bisporus*, the cultivated mushroom. Indian J. Mycol. Plant. Pathol. 7: 5-10.

Hayes WA (1981). Interrelation studies of physical, chemical and biological factors in casing soils and relationships with productivity in commercial culture of *Agaricus bisporus* Lang. Pilat. Mush. Sci. 11(1): 163-179.

Holtz B, Scheisler L (1986). Utilization of fatty acids by *Agaricus bisporus* in commercial culture, Mycologia, 78 (5): 722-727.

Kachroo JL, Ahmad N, Kaul TN (1979). Experiments in the improvement of compost formulae and procedure in *Agaricus bisporus* cultivation. The Mush. J. 82: 433- 441.

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.

Randle PE (1984). Supplementation of mushrooms composts: A review. Mush. J. 51: 241-269.

Randle PH, Hayes WA (1972). Progress in experimentation on the efficiency of composting and compost. Mushroom Sci. 8:789-795.

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, pp: 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.* Indian 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.
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*. Indian J. Mushrooms 2(2): 18-20.
Yalinkilic MK, Altun L, Baysal E, Demirci Z (1994). Development of mushroom cultivation techniques in Eastern Black Sea Region of Turkey. Project of the Scientific and Technical Research Council of Turkey (TUBITAK), No. TOAG 985, pp. 377.