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The effects of various casing materials on yield and quantitative indices of *Agaricuss ubrufescens* and *Agaricuss bisporus*

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Abstract

Casing is a staple part of mushroom cultivation with profound impact on fructification and crop yield. This survey aimed to scrutinize the influence of various casing alternative materialson the fruiting bodies, yield, and duration of production cycle of *Agaricuss ubrufescens* and *Agaricuss bisporus*. Evaluated casing treatments included common soil, Duch soil, spent mushroom compost from *A. bisporus*, vermicompost from spent mushroom compost, vermicompost from municipal solid waste, zeolite and their combinations as well.Using SPSS, analysis of data was conducted in a completely randomized factorial design and LSD test. The findings revealed that the highest productivity of *A. bisporus*was obtained by using casing layer comprised of Duch soil + vermicompost from municipal solid waste (2:1).The most efficient casing for *A. subrufescence* were common soil + Duch soil (1:1),common soil + vermicompost from spent mushroom compost (2:1), common soil + vermicompost from municipal solid waste (2:1), respectively. Mixing vermicompost from spent mushroom compost and vermicompost from municipal solid waste with common soil led to substantial reduction of growth period and cropping period of *A. subrufescence*. In conclusion, this study highlight the efficiency of using vermicompost as an alternative casing material for both improving productivity and accelerating production cycle.

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Introduction

Likewise *A.subrufescens*,*A.bisporus* is a Basidiomycete fungus, commonly known as white, button or table mushroom.Studies indicated that compared to *A. bisporus*, A. *subrufescens* favors higher temperature and lightening for fruiting bodies development and colonization (Gregori *et al.,* 2008). Beyond question,casing layer is a staple part of mushroom cultivation that greatly stimulate the fructification (Mac Canna, 1984).Despite the unavailability, extraction problem, and environmental nuances, the use of peat moss in mushroom industry is still very common across the globe (Bustamante *et al.,* 2008).Spent mushroom substrate left after final crop harvest is a matter of concern due to environmental pollution such as ground water contamination, whichput the ecosystem in jeopardy.

Owing to the health and nutrition benefits of mushrooms, they are processed, produced and consumed in many countries on a large scale. There has been a significant raise in the cultivation and consumption of edible mushroomsbecause of their nutritional value, therapeutic and medicinal purposes. Himematsutake (*Agaricuss ubrufescens* Peckheretofore known as *A.blazei* Murrill, or *A.brasiliensis*), also called Royal Sun Agaricus, is native to Brazil and has been traditionally used as a health food source and medicinal mushroom (Kerrigan *et al.,* 2007; Wasser *et al.,* 2002; Gan *et al.,* 2013). The presence of remarkable anticancer properties of*A. blazei*, which might bemediated by its six special polysaccharides (β-Glucans)(Hyodo *et al.,* 2005) and blazein (Itoh *et al.,* 2008), has caught attention of many scientists.

As described by Flegg (1961) the high electrical conductivity of casing material may exert a negative influence on the fruit body induction of *A. bisporus*, hence the need for leaching or mixing spent mushroom compost with another casing material. Since mushroom production is escalating, it demands a paradigm shift in selecting a valid alternative component which is congenial to environment, cost-effective, and highly productive comply with different varieties. Reutilization of spent mushroom compost can help to alleviate residual spent compost (a major environmental issue in mushroom growing) and reduce costs, which may result in an economic impact for the mushroom industry.

Study about this topic is important for food science. Because of that, this investigation was designed to assess the 21 different treatments for each species in order to find a valid alternative to sphagnum peat moss, which is a threatened resource and expensive, difficult or impossible to obtain in certain areas in the world.

Material and method

Research location

This research was conducted at the Isfahan (Khorasgan) Branch, of the Islamic Azad University, Department of Horticulture in April 2013.After purchasing overgrown grain with fungal mycelia at Bishe Company (Charmahal-Bakhtiari, Iran), they were used in experiments.The myceliumstrains used in experiment consisted ofSylvan A15 (Sylvan Spawn. Ltd, Peterborough, United Kingdom) and Iwade 101 for *A. bisporus* and *A. subrufescens*respectively.After preparation, each medium block wasputinto plastic bagsand placed on plastic wire shelves.

Casing material treatments

Vermicompost from spent mushroom compost was purchased from the ClarCompany. Spent mushroom compost was provided from theCharmahal-Bakhtiari location. Common soil was supplied from Talesh in the north of Iran and from Shiraz. Duch soil was purchased from the Netherlands. The preparation technique was the same as for the commercial compost production system of *A. bisporus*.

Spawning

Each medium block (60 × 40 cm) was made upof 20 kilograms of substrate materialversus 1.5% w/w spawningrate (in relation to the wet weight of substrate), and incubated at 25°C in darkness with a

relative humidity of65±5% and a CO_2 content of 2100 ppm for15 days.

Casing treatments

With fully developed mycelium, the casing with an 85-90% water content wasdistributed over the surface of the compost at a depth of 3 cm.Having strewn the compost with the casing layers, they weredisinfected by applying carbendazim (30 g / 50 L water), and diazinon(100 mL / 50 L water) as fungicide and pesticide respectively.

Casing treatmentswere comprised ofCommon soil (CS), Duch soil (DS), spent mushroom compost from *A. bisporus* (SMC), vermicompost from spent mushroom compost (VSMC), vermicompost from municipal solid waste (VMSW), zeolite (Z) and their combinations as well.

Physical-chemical characterization of the casing materials

Table 1 illustrates the characteristics of the casing materials before and after consumption. The levels of manganese and iron were determined by using an atomic absorption spectrophotometer (AAS) (Linsday *et al.,* 1978). The phosphorus concentration was assessed using a spectrophotometer apparatus (John, 1970). Determination of potassium, calcium and magnesium content was executed using a flame photometer instrument (Snel, 1949).

Pinning and harvest

The environmental variables were controlled in order to obtain 3 flushes over the crop. Subsequently, at the time of growing phase, room temperature was gradually reduced to 18±1 °C with a relative humidity of 90±5% and a CO_2 content of 1800 ppm for fruiting bodies induction.After developing pin head to a large mushroom, they were harvested daily at their optimal commercial stagein accordance with morphological stage of 2, 3 and 4 described by Hammond and Nichols (1976).

Evaluated parameters

The agronomic performance was evaluated by mean yields of three flushes, salable fresh weight, debris fresh weight, fruitbody fresh weight, number of fruit body per block (100 × 100 cm), pileus diameter, and ash percentage.Subsequently, cropping period, time-interval between spawning to pin head formation (PHF), and growing period were investigated to estimate the allotted time for mushroom production.The time-interval between spawning till the end of third flush picking was considered as a growing period and the time-interval between picking the first flush till the end of the third flush picking was considered as a cropping period.

Statistical analysis

The experiment was conducted using two strains and 21 casing materials, totaling 42 treatments and each treatment replicated 6 times. Using SPSS statistical analysis software, completely randomized factorial design was executed to analyze the data.The significance of the differences between the means was determined by using LSD test at 5% probability level.

Results

Analysis of data

Based on the physical-chemical characteristics denoted in table 1, the levels of EC, magnesium, potassium and phosphorus displayed the highest changes after media consumption. For instance, in the case of *A. bisporus* the amount of EC in DS rose by 2.4 to 3.5, whereas it diminished to 1.3 for *A. subrufescens*. RegardingVMSW, after consumptionthe EC level increased for both mushrooms. The amount of magnesium level in DS substantially decreased after cultivation of both mushrooms. The considerable reduction of the DS potassium concentrationsafter consumption for both mushrooms were also evident.

Consumed zeolite media for both mushrooms resulted in increasing the casingphosphorus content, especially for *A. subrufescens*. By looking at the level of Fe content and casing ash percentage, it can be

seen that CS consumption resulted in increasing Fe content, and DS consumption led to increasing ash percentage. Passing on now to table 2 we can see that common soil had the highest water holding capacity, whereas zeolite,Duch soil and VSMC had the lowest respectively. Based on theagronomic performances presented in table 3, the highest yield were obtained by applying DS + VMSW (2:1) for*A. bisporus*,and also CS + DS (1:1) for *A.subrufescens* and they followed by CS + VSMC (2:1), and CS + VMSW (2:1) for both mushrooms. In the same way,the highest salable fresh weight were cohered with the highest yield results. These results showed analogous changes withthe amount of debris fresh weigh (Table 3).

Table 1. Physical-chemical characteristics of the casing materials before and after consumption.

	Casing materials	EC	PH	Ca	Mg	K	P	Mn	Fe	Ash
		(dSm^{-1})	(-)	($g\ kg^{-1}$)		(%)	($mg\ kg^{-1}$)	($mg\ kg^{-1}$)		(%)
Before consumption	CS	4.5	7.4	18.9	14.7	13	77.3	12	18	52
	DS	2.4	7.6	22.1	15.6	1	121.8	4	83.4	63
	SMC	8.5	7.6	15.2	11.7	36	124.9	1.5	7	47
	VSMC	4.2	7.4	20.2	14.7	11	55.4	43	24	51
	VMSW	1.2	8	4.3	4.4	9	233.9	22	10	76
	Z	0.2	9.7	5	3.7	4.6	16.4	0.7	2.4	95
After consumption for *A. bisporus*	CS	3.4	7.3	21.3	16.6	3.2	39.9	5.8	41.2	60
	DS	3.5	7	8.6	6.7	4.6	111.5	4.5	84.4	37.5
	SMC	7.8	7.4	16.3	13.4	8	115.1	6	5.8	50
	VSMC	5.6	7	18.7	14	13.2	121.3	65	28	80
	VMSW	3.7	7.2	4	18	11.2	197.8	18	14	77.5
	Z	0.7	8.5	5.6	4.4	5.5	100.7	3	2.6	90
After consumption for *A. subrufescens*	CS	3.1	7.5	22.1	15	3.8	40.5	6.2	75.4	59
	DS	1.3	7.4	6.6	6	0.3	81.3	5.2	85.2	21
	SMC	7.9	7.2	16	12.2	24	100	2.4	5.3	49.5
	VSMC	4.5	7.2	18.2	13.8	12.8	83.1	45.6	25.7	48
	VMSW	3.1	7.5	5.6	5.2	11.4	242.3	20.4	12.6	74.5
	Z	0.9	8.3	6.9	5.4	5.3	230.3	2.2	3.2	75

[1]EC = electrical conductivity.

Table 2. Water holding capacity (WHC) of casing materials prior to consumption.

CS	DS	SMC	VSMC	VMSW	Z
133.8	40.5	95.2	50	97	39

Considering thequantitative attributes (yield, and salable fresh weight), the most appropriate casing layer would seem to beCS + DS (1:1)for*A.subrufescens*, and DS + VMSW (2:1)for *A. bisporus* followed by CS + VSMC (2:1), and CS + VMSW (2:1). For *A.subrufescens*,the beneficiary effects of CS + VSMC (2:1),and CS + VMSW (2:1) took precedence over *A. bisporus* (Table 3, 4). The highest mushroom ash percentages were obtained by cultivation of *A.subrufescens*in SMC, and *A. bisporus* in VSMC + VMSW (1:1) respectively (Table 4). The highest number of fruit body were observed on CS + DS (1:1) for *A.subrufescens*.

Data revealed that casing media with highest yield (Table 3) are also linked with producing large mushrooms which had insignificant differences compared to mushrooms with highest pileus diameter

(Table 4). As shown in table 5, in the case of *A.subrufescens*, the results implythat in comparison with applying common soil unaccompanied by other materials as a casing layer, when vermicompost from agricultural waste and municipal solid waste weremixedinto common soil, the duration of growing period and cropping period reduced substantially

Table 3. The Effects of various casing layer treatments on agronomic performances of *A. bisporus*(B)and *A. subrufescens* (S).

Casing	Yield (kg m^{-2})		Salable fresh weight (kg m^{-2})		Debris fresh weight (kg m^{-2})		Fruitbody fresh weight (g)	
	B	S	B	S	B	S	B	S
CS	8.2f-j	10d-g	7.2f-j	8.9ef	1d-h	1.2b-f	55a-e	48.3d-g
DS	10d-g	12.5bcd	9ef	10.9b-e	1c-h	1.7abc	53.3a-g	50.7b-g
SMC	3.9lm	4.1lm	3.3lm	3.6lm	0.5f-j	0.5g-j	51.6a-g	49d-g
VSMC	5.6j-m	5.1klm	4.9i-m	4.5klm	0.7e-j	0.7e-j	50.8a-g	47.7efg
VMSW	12.3cde	5.7j-m	11.1b-e	5i-m	1.2c-g	0.7e-j	57.4abc	47.6efg
Z	6.1h-m	3.1lm	5.4h-l	2.9m	0.7e-j	0.2j	51a-g	48.2d-g
CS + DS (1:1)	13.7abc	15.4a	11.9abc	13.8a	1.8ab	1.6a-d	49.6c-g	47.3efg
CS + SMC (2:1)	5.6j-m	8.9fgh	5i-m	8.1fg	0.6f-j	0.8e-j	48.7d-g	48.5d-g
CS + VSMC (2:1)	10.6def	13.9abc	9.5c-f	12.2ab	1d-h	1.7ab	54.4a-f	52.5a-g
CS + VMSW (2:1)	10.3def	13.5abc	9.3def	12.6ab	1d-g	1d-h	54a-f	51.4a-g
CS + Z (2:1)	3.2lm	8.6f-i	2.8m	7.8fgh	0.4hij	0.8e-j	45.4g	48.2efg
DS + SMC (2:1)	4.5klm	8.3f-j	3.7lm	7.4f-i	0.7e-j	0.8e-j	58ab	50.6b-g
DS + VSMC (2:1)	9fg	8.6f-i	7.6fgh	8.1fg	1.3b-e	0.5f-j	56.3a-d	46.7fg
DS + VMSW (2:1)	15.2ab	12.7a-d	13.2ab	11.8a-d	2a	0.9e-i	57.3 abc	47.7efg
DS + Z (2:1)	5.9i-m	9.6efg	5.4h-l	8.8ef	0.6f-j	0.8f-j	58.7a	48.6d-g
VSMC + VMSW (1:1)	4.6klm	9.6efg	4lm	9ef	0.7e-j	0.6f-j	54.4a-f	50.4b-g
VSMC + SMC (1:1)	4.3lm	5.1klm	3.8lm	4.7j-m	0.5g-j	0.4hij	47.2efg	46.5fg
VMSW + SMC (1:1)	3.6lm	4.9klm	3.1lm	4.5klm	0.5g-j	0.4hij	47.5efg	48.4d-g
VSMC + Z (1:1)	4.4lm	6.1h-l	3.8lm	5.7g-l	0.6f-j	0.4hij	52.8a-g	47.8efg
VMSW + Z (1:1)	4lm	7.4g-k	3.5lm	6.9f-k	0.5g-j	0.5g-j	52.4a-g	50.3b-g
SMC + Z (1:1)	3.4lm	5.7j-m	3lm	5.4h-m	0.5hij	0.2ij	49.4c-g	47.2efg

[1]Means having the same letter(s) were not significantly different at 5% level according to LSD test.Common soil (CS), Duch soil (DS), spent mushroom compost from *A. bisporus* (SMC), vermicompost from spent mushroom compost (VSMC), vermicompost from municipal solid waste (VMSW) and zeolite (Z).

Discussion

So far, there is relatively little information on the use of vermicomposted materials in *Agaricus* cultivation. There is also not an extensive bibliography for *A. subrufescens* cultivation processas investigated in this study. There is a close correspondence between water holding capacity (WHC), which is a requirement for a good casing, and mushroom fresh weight. The higher level of common soil's WHC, as outlined in table 1, seemingly plays a crucialrole inpromotingthe crop yield. On the other hand, in the case of SMC, the higher electrical conductivity could negate its positive aspect of having high WHC, which eventuated in less productivity.Zeolite PH was also higher than optimal range in comparison with other casing substrates and this could exert a negative influence on mushroom yield (Table 1, 2, 3 and 4). Considering the *A. bisporus* agronomic performances, DS + VMSW (2:1), and CS + DS (1:1) were the most productive casing treatments, respectively (Table 3 and 4). Accordingly, the lower level of EC of CS, DS, and VMSW must be regarded as a decisive contributory factor in yield improvement.

Table 4. The Effects of various casing layer treatments on number of fruitbody, pileus size and ash percentage of *A. bisporus*(B)and *A. subrufescens* (S).

Casing	No. of Fruitbodym^{-2}		Pileus diameter (mm)		Ash (%)	
	B	S	B	S	B	S
CS	149.3h-l	212.7d-g	54.3de	47.7f	9.3g-m	11.7b-e
DS	183.7f-i	265bcd	60a-d	56.7cde	10.7c-h	10.5d-h
SMC	71no	82.7mno	60.7a-d	59.3a-e	8l-o	13.8a
VSMC	103.3l-o	151h-l	61.7a-d	63a-d	8.2k-o	11.5b-f
VMSW	224.7c-f	178f-j	67.3abc	63a-d	10.5d-h	12bcd
Z	111.7k-o	122.7j-n	60.3a-d	38f	10.5d-h	11.7b-e
CS + DS (1:1)	249.3b-e	332a	63.7a-d	61a-d	11.8bcd	13.3ab
CS + SMC (2:1)	103.3l-o	188.3f-i	68abc	57.7a-e	9.3g-m	11.3c-g
CS + VSMC (2:1)	193fgh	291ab	69.7ab	68.7abc	10.3d-i	11c-h
CS + VMSW (2:1)	188f-i	286.3ab	60.3a-d	66a-d	10.5d-h	11.3c-g
CS + Z (2:1)	59o	182f-i	60.3a-d	61a-d	7.7mno	10.8c-h
DS + SMC (2:1)	82mno	173.7f-j	64a-d	57b-e	10d-k	10.8c-h
DS + VSMC (2:1)	164g-k	182.3f-i	70a	59.3a-e	9h-n	10.2d-j
DS + VMSW (2:1)	278bc	269.3bc	62a-d	60.3a-d	10.5d-h	10.5d-h
DS + Z (2:1)	108.7k-o	205e-h	57b-e	60a-d	8.5i-n	10.7c-h
VSMC + VMSW (1:1)	67mno	110.3e-h	65a-d	63.3a-d	12.5abc	10.7c-h
VSMC + SMC (1:1)	78.7mno	108.3k-o	58.3a-e	63.7a-d	6.3o	10.2d-j
VMSW + SMC (1:1)	67no	110.3k-o	64.3a-d	58.7a-e	7.7mno	10.2d-j
VSMC + Z (1:1)	78.7mno	131.7i-m	61.3a-d	58.7a-e	8.3k-n	9.5f-m
VMSW + Z (1:1)	74.7mno	152h-l	56.3cde	62.7a-d	7.3no	9.5f-m
SMC + Z (1:1)	63.6 no	122j-n	63a-d	40.3f	7.3no	9.7e-l

[1]Means having the same letter(s) were not significantly different at 5% level according to LSD test.Common soil (CS), Duch soil (DS), spent mushroom compost from *A. bisporus* (SMC), vermicompost from spent mushroom compost (VSMC), vermicompost from municipal solid waste (VMSW) and zeolite (Z).

In the same way, application of CS + DS (1:1) led to the highest productivity of *A. subrufescencen* (Table 3) along with the highest number of fruit body (Table 4). The best results were then followed with the application ofCS + VSMC (2:1), CS + VMSW (2:1) and DS + VMSW (2:1), respectively (Table 3 and 4). The high level of productivity ofCS, and DS components (Table 4) might also be attributed to the better absorption of phosphorous, which is whyit has been diminished after media consumption (Table1).

Findings of this study are consistent with those documented previously that verified thesuperior effects of vermicompost on yield of marketable strawberries in comparison with inorganic fertilizer (Arancon *et al.,* 2004). As well as this, in 2008 Pardo-Giménez and Pardo-González demonstrated the advantages of reusing spent mushroom substrate as an alternative casing material, which reduces costs and the environmental impact of waste disposal. Interestingly, presented data in Table 5 revealed that when VSMC and VMSW were mixed into common soil, growth period and cropping period of *A. subrufescence* significantly decreased. In conclusion, this study emphasize the beneficiary effects of vermicompost usage as a supplementary ingredient of casing not only on heightening productivity, but also on accelerating the process of mushroom development, which reduces the time needed for pests to become established and proliferate.

Table 5. The Effects of various casing layer treatments on growing period, time-interval between spawning to pin head formation (PHF) and cropping period of *A. bisporus*(B)and *A. subrufescens* (S).

Casing	Growing period (day)		Spawning to PHF (day)		Cropping period (day)	
	B	S	B	S	B	S
CS	78a-d	78.3abc	26.3j	27.3hij	44a-d	44.3abc
DS	77.3a-d	77a-e	27ij	26.3j	43.3a-d	43a-e
SMC	71.3f-i	78a-d	31.3bc	32b	37.3f-i	44.3abc
VSMC	78a-d	76a-f	31bcd	30.7b-e	44a-d	42a-f
VMSW	77.7a-d	76.3a-e	30c-f	31.3bc	43.7a-d	42.3a-e
Z	70.3hij	66.7j	30c-f	35.7a	36.3hij	32.7j
CS + DS (1:1)	79.7a	76a-f	26j	26j	45.7a	42a-f
CS + SMC (2:1)	75a-h	72.3e-i	29.7c-f	29.7c-f	41a-h	38.3e-i
CS + VSMC (2:1)	78.3abc	72.3e-i	28.7f-i	28.7f-i	44.3abc	38.3e-i
CS + VMSW (2:1)	77.3a-d	73.3d-h	29e-h	29e-h	43.3a-d	39.3d-h
CS + Z (2:1)	79ab	73.3d-h	28.7f-i	31bcd	45ab	39.3d-h
DS + SMC (2:1)	74.7b-h	73.3d-h	30c-f	31bcd	40.7b-h	39.3d-h
DS + VSMC (2:1)	77.3a-d	68.3ij	27.7g-j	31.3cb	43.3a-d	34.3ij
DS + VMSW (2:1)	77.7a-d	68.7ij	27.3hij	31.3cb	43.7a-d	34.7ij
DS + Z (2:1)	74.7b-h	74c-h	26.7j	29.7c-f	40.7b-h	40c-h
VSMC + VMSW (1:1)	78.3abc	77a-e	29.7c-f	39.3d-g	44.3abc	43a-e
VSMC + SMC (1:1)	75.3a-g	79.3ab	30.7b-e	31.3cb	41.3a-g	45.3ab
VMSW + SMC (1:1)	75.3a-g	77.7a-d	31bcd	30.3b-f	41.3a-g	43.7a-d
VSMC + Z (1:1)	75a-h	77a-e	30.3b-f	30c-f	41a-h	43a-e
VMSW + Z (1:1)	75.3a-g	75.3a-g	29e-h	29.3d-g	41.3a-g	43a-g
SMC + Z (1:1)	73.7c-h	71ghi	31bcd	29.7c-f	39.7c-h	37ghi

[1]Means having the same letter(s) were not significantly different at 5% level according to LSD test. Common soil (CS), Duch soil (DS), spent mushroom compost from *A. bisporus* (SMC), vermicompost from spent mushroom compost (VSMC), vermicompost from municipal solid waste (VMSW) and zeolite (Z). Evaluated variables were as follows: growing period, spawning time to harvesting last (third) flush; cropping period, from the time of the first harvest to the last harvest of third flush.

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