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Spent Mushroom Substate (SMS) Usability as Casing Material in *Agaricus bisporus* Cultivation

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ABSTRACT

In this research, the usability of spent mushroom compost/substrate (SMC/SMS) as casing material was investigated. For this purpose, different volumes of peat and spent mushroom substrate (peat, peat + SMS (1/1), peat + SMS (1/2), peat + SMS (2/1), SMS) were used as casing material. The effects of spent mushroom substrate waste used as casing material and different volumes of peat applications on cap length, cap diameter, stipe length, stipe diameter, hardness, number of mushrooms, average mushroom weight, yield of cultivated mushrooms were determined. Different casing material applications affected stipe length, hardness, number of mushrooms, average mushroom weight and yield. Although the highest yield was obtained from peat application (59.86 kg 100 kg^{-1} compost), it has been shown that spent mushroom substrate waste can be used in casing material mixtures in mushroom cultivation.

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Introduction

Cultivated mushroom production in the world is increasing regularly, and the annual increase rate is distributed between 6-7% on average (Abak, 2024). According to FAO 2022 records, the total world mushroom and truffle production amount is 48 million tons, and in our country, it is around 65 thousand tons (FAO, 2024). The unique taste, aroma, and nutritional value of mushrooms increase the demand for them in the world (Sun et al., 2020). Mushrooms contain biological active substances (e.g., antioxidant, antitumor, antimicrobial, anti-inflammatory) that are beneficial for human health (Baktemur et al., 2022).

The compost resulting after production in mushroom cultivation is called spent mushroom compost (SMC) or spent mushroom substrate (SMS) (Phan & Sabaratnam, 2012; Pekşen & Yamaç, 2016; Jasińska, 2018). It is reported that 5 kg of SMS are released for each kg of mushrooms produced, regardless of the mushroom species (Semple et al., 2001; Williams et al., 2001; Lau et al., 2003; Ma et al., 2014; Jasińska, 2018). The amount of SMS released as a result of mushroom production is estimated to be around 240 million tons/year in the world and 325 thousand tons/year in Turkey.

The increase in cultivated mushroom production in the world and in Turkey every year also causes an increase in the amount of compost that becomes waste after harvest. The SMS released in large quantities is removed from the enterprises by burning, throwing it in the trash, or mixing it with the soil in agricultural areas. These practices are either uneconomic for businesses or create a significant environmental pollution problem. However, SMS is a material that can be used in many different areas and brought into the economy (Pekşen & Yamaç, 2016).

It is possible to utilize used mushroom compost in different ways. Some of these are; source of organic matter for plants grown in greenhouses (Çelikel & Çağlar 1999; Çelikel, 1999a; Polat et al., 2009; Peker, 2018) and in open fields (Courtney, & Mullen, 2008; Aydın, 2009; Sagar, et al. 2009; Uğur, 2019), in seedling production (Medina et al. 2009; Kwack et al. 2012), ornamental plant cultivation (Birben 1998; Çiçek, 2004; Sönmez, 2009), growing media in soilless culture (Çelikel, 1999b), compost in the production of different mushroom species (Gimenez, 2008; Mamiro & Royse 2008; Cunha Zied et al. 2020), casing material mushroom cultivation (Pardo Giménez & Pardo-González 2008; Pardo-Giménez et al. 2010; Pardo-Giménez et al. 2011), animal feed (Ayala et al., 2011; Kim et al., 2011), vermicompost production material (Pekşen & Yamaç, 2016), bioremediation agent (Lau et al., 2003; Phan, and Sabaratnam 2012; Zhou et al., 2014; Rinker, 2017), plant disease and pest management (Gent et al., 1999; Litterick et al., 2004; Gea et al., 2014), enzyme production (Phan, & Sabaratnam 2012; Kökcü, 2020), fuel and biogas production (Zhu et al., 2013; Kapu et al., 2012; Pérez-Chávez et al., 2019) and particleboard manufacturing (Yağlıca, 2019).

The fact that SMS is low-cost, available in large quantities and rich in organic matter makes its use in agricultural production attractive (Pekşen & Yamaç, 2016; Shimira et al., 2022). However, the instability of SMS content, low water retention capacity, high ammonia content and high soluble salt level are the most important factors that may limit its use in plant production (Holozlu, 2013; Sütçü, 2018; Wever et al., 2005; Jasińska, 2018). Before evaluating the SMS, it is mandatory to reduce the EC value to the desired levels. Many researchers recommend that, due to the high salt content it contains, it should be made into piles in the field and left to decompose for 1-2 years (Birben, 1998; Guo et al., 2001; Polat et al., 2004;), and subjected to a certain washing process (Wever et al., 2005; Polat et al., 2009; Holozlu, 2013; Sütçü, 2018) or additions such as soil and peat it is recommended to use suitable mixtures prepared by making plants in plant cultivation (Birben, 1998; Çaycı et al., 1998; Kütük, 2000; Eren & Boztok, 2013).

Casing material provides the transition of *Agaricus bisporus* mycelia from the vegetative to the generative cycle (Özşimşir & Arın, 1996). In addition to encouraging fungus formation, casing material also supports the adhesion of cultivated fungus carpophores and meets the water requirement of the fungus (Çetin et al., 2016). The physical, chemical properties and biological structure of the casing material directly affect the yield and quality of the mushroom produced. For this reason, the most commonly preferred material in commercial mushroom production is peat (Erkel, 1992; Çolak, 2004; Eren, 2008; Pardo-Giménez, et al., 2017). However, the availability of peat, the depletion of reserves, and the instability of its structure due to changes in ecosystems have led to the search for alternative materials (Pardo-Giménez et al., 2017). Although many natural inorganic and organic materials, as well as peat moss, are used as casing material, very few of them have physical and chemical properties that can be used instead of peat (Pardo et al., 1999).

In this study, the possibility of using spent mushroom compost/substates kept in open areas for a year as a casing material, as an alternative to peat, which is widely used in *Agaricus bisporus* cultivation, was investigated.

Materials and Methods

The research was conducted at Selçuk University, Faculty of Agriculture, Department of Horticulture, between November and January 2019-2020. In the study, 60 bags containing 10 kg of compost planted with mycelia of the Sylvan A15 variety of *Agaricus bisporus* species, obtained from Mega Tesnim A.Ş., were used. The used mushroom composts resulting from mushroom production a year ago were stacked in an open area and then kept as a casing material material.

Preparation of the Growing Room

The growth room was sprayed with 3% formaldehyde and the next day, after the room was ventilated, the bags containing compost were placed on the shelves in the growth room. The tools used in the room were also treated with 2% formaldehyde. After the bags placed on the shelves were opened, they were covered with paper. (Figure 1).

Figure 1. Covering compost with paper

I. Mycelial Development Period

During the mycelial development phase, the room temperature was kept at 21-22°C for 2 weeks. Compost temperature is 2-4°C higher than room temperature. In this regard, the compost temperature was kept between 25-26 ^{0}C. A thermometer was placed in the room to control the temperature. During the micelle wrapping phase, the indoor humidity was tried to be kept at 90-95%. The papers on the compost were checked and moistened every day. Humidity and temperature control were monitored regularly until the mycelia surrounded the compost.

Casing Material Saying, Establishment of the Experiment and II. Mycelial Development Period

After the mycelia completely surrounded the compost, the papers on the compost were removed and a 4 cm thick casing material was laid. (Figure 2). Different volumes of peat and spent mushroom substrate (peat, peat + SMS (1/1), peat + SMS (1/2), peat + SMS (2/1), SMS) were used as casing material. For each application, 4 replicates and 3 bags were used in each repetition. The casing material was irrigated with irrigation water after laying. After all the procedures were completed, the room was sprayed with 1% formaldehyde. After the casing material was laid, the temperature was not changed for 3-4 days, allowing the mycelia to jump into the casing material. Then, the temperature was gradually reduced to 16 ^{0}C and an attempt was made to keep it constant at this temperature. After the emergence of mycelia on the upper surfaces of the casing material was observed, the part of the casing material equal to the compost was mixed. With this process, which we call scratching, the mycelia were distributed evenly throughout the casing material.

Harvest Period

Harvest started 20 days after the casing material was laid. The mushroom cap diameter was harvested when it was 4.5-5 cm (Figure 3). The dirty bottom part of the harvested mushrooms was removed with a sharp knife, the top was cleaned, then they were weighed, measured and packaged.

Figure 2. Laying casing material on compost

Figure 3. View of mushrooms that have reached harvest size

Table 1. The effect of SMC used as casing material on the yield and quality of cultivated mushrooms.

Treatments	CL	CD	SL	SD	F	NM	AMW	Y
Peat	21.36a	39.90a	20.48ab	18.64a	2.36b	366.67a	15.76a	59.87a
Peat + SMS (1/1)	21.31a	39.20a	21.76a	17.63a	3.11a	306.40b	14.57bc	45.62b
Peat + SMS (1/2)	21.25a	38.73a	19.87ab	17.28a	2.47b	295.53bc	14.87b	41.39bc
Peat + SMS (2/1)	21.06a	38.67a	20.58ab	18.81a	2.36b	315.53ab	14.85b	49.43b
SMC	21.33a	39.48a	18.75b	18.59a	2.39b	249.17c	13.95c	34.77c

C: Cap length (mm); CD: Cap diameter (mm); SL: Stipe length (mm); SD: Stipe diameter (mm); F: Firmness (kg/cm^2); NM: Number of mushrooms (fruits/bag); AMW: Average mushroom weight (g); Y: Yield (kg 100 kg^{-1} compost); *Means with different letters in the same column were significantly different ($p<0.05$). SMC: Spent mushroom substrate

Analysis and Measurements

In the study, in all applications, mushrooms obtained from each harvest were measured separately and at the end of the 45-day harvest period, yield (kg 100 kg^{-1} compost), number of mushrooms (fruits/bag), and average mushroom weight (g) were determined. Cap diameter (mm), cap length (mm), stipe diameter (mm), stipe length (mm), hardness (kg/cm^2) measurements were determined by measurements made on 10 mushroom samples randomly selected from all repetitions of each application. Hardness measurements were made with the help of a penetrometer. Hat diameter, hat length, hat diameter and hat length were measured using a digital caliper with an accuracy of +0.01 mm. The experiment was set up with 4 replications according to the random parcel design and 3 bags were used in each replication. The obtained data were grouped using the Duncan multiple comparison test by performing variance analysis with the SPSS statistical program. In their evaluation, the significance between the differences (5%) was determined.

Results and Discussion

In the study, the effects of spent mushroom substrate and peat and their mixtures in different volumes as casing material on the cap height, cap diameter, stipe length, stipe diameter, hardness, number of mushrooms, average mushroom weight and yield of cultivated mushrooms were statistically investigated. As a result, while the effect of the media used as casing material on stipe length, hardness, number of mushrooms, average mushroom weight and total yield was found to be statistically significant, its effect on cap height, cap diameter and stipe diameter was insignificant (Table 1).

The effect of spent mushroom substrate (SMC), peat and their mixtures in different volumes on the stem length of cultivated mushrooms was found to be statistically significant. The highest stipe length value was obtained from the peat + SMC (1/1) application, 21.76 mm, and the lowest value, 18.75 mm, was obtained from the SMC application (Table 1). According to the results of cover soil trials in *Agaricus bisporus* cultivation, it is reported that the stem length values of mushrooms vary between 15.8-30.6 mm (Çetin & Eren, 2017; Önel, 2020; Duran et al., 2023).

The effect of different casing material used on mushroom firmness was found to be statistically significant. The highest value in hardness measurements was obtained from peat + SMC (1/1) application (3.11 kg/cm^2) (Table 1). It is compatible with the hardness values (1.42-3.87 kg/cm^2) determined by Duran et al., (2023).

The effect of different casing material on the number of mushrooms was found to be statistically significant. The highest number of mushrooms was obtained from the peat application (366,67 fruits/bag) and the lowest was obtained from the SMC application (249.17 fruits/bag) (Table 1). In the study of vermicompost, rose oil processing waste compost, and spent coconut fiber as casing material in button mushroom cultivation, they obtained a mushroom count of 4.88-184.83 fruits/bag (Duran et al., 2023). In his study conducted by Yücel, 2024, they obtained the number of mushrooms between 295.5-337.8 fruits/bag. It is seen that the number of mushrooms obtained decreases depending on the SMC ratio used as casing material (Table 1). It can be said that this is due to the increasing EC value in the casing material.

The effect of different casing material mixtures on the average mushroom weight was found to be statistically significant. While the highest mushroom weight was obtained from peat application with 15.76 g, the lowest value was obtained from SMC application with 13.95 g. In different studies on casing material, average mushroom weights varied between 12.8-23.8 g (Çetin & Eren , 2017; Duran et al., 2023; Yücel, 2024). Similar to the number of mushrooms, the mushroom weights obtained decreased due to the increasing SMC rate (Table 1).

The effect of spent mushroom substrate and peat and their mixtures in different volumes on the yield of cultivated mushrooms was found to be statistically significant. The highest yield value (59.86 kg 100 kg^{-1} compost) was obtained from peat application, and the lowest yield value was obtained from SMC application (34.77 kg 100 kg^{-1} compost) (Table 1). In the study investigating the possibility of using peat mixtures of seagrass, tea waste, sugar beet lime and spent mushroom substrate as casing material in mushroom cultivation, a yield of 3.55-21.96 kg per 100kg^{-1} compost was obtained (Eren & Boztok, 2013). Polat & Önel, 2021, in their study where they used perlite and vermicompost as casing material, they achieved a yield of 22.73 - 35.69 kg per 100 kg^{-1}. In the experiment, taking the product in 4 flash periods for 45 days increased the yield values.

Conclusion

Peat is an ideal casing material for cultivated mushroom (*Agaricus bisporus*) (Erkel, 1992; Çolak, 2004; Eren, 2008; Pardo-Giménez, et al. 2017). However, peat is also widely used in the seedling sector and soilless agriculture. It is not a sustainable resource in the future due to the limited resources of peat in the world and the damage it causes to the environment during its extraction. Just as other natural resources will run out in the near future, peat resources will also run out. As long as human beings exist, they will be fed, and it is inevitable for agricultural activities to be sustainable in order to be fed. For this reason, some new materials that can replace peat in cultivated mushroom cultivation have been emphasized and various studies have been conducted on this subject (Gülser & Pekşen, 2003; Çolak, 2004; Taşkın et al., 2008; Çetin & Eren, 2017). It has been reported that materials such as composted pine tree bark, wood sawdust, tree bark, spent mushroom substrate, coconut fiber, sugar beet lime, seagrass, tea waste and waste paper can be among the alternative casing material (Gülser & Pekşen, 2003; Pardo-Giménez & Pardo- González, 2008; Pardo-Giménez et al., 2017; Boztok, 2013).

SMC is a potential material that can be used as casing material. As can be understood from the efficiency elements of the experiment, SMC can be an alternative material to peat, provided that the salinity problem is completely eliminated by practices such as washing, keeping it in open areas or mixing it with low conductivity materials.

Declarations

Conflicts of Interest

The author declare no conflict of interest.

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