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PRODUCTION OF *PLEUROTUS OSTREATUS*, *PLEUROTUS CITRINOPILEATUS* AND *PLEUROTUS DJAMOR* IN DIFFERENT CONTENTS AND SOME PHYSICAL ANALYSIS

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Abstract

In this study, some physical properties of oyster mushroom (*P. ostreatus*), yellow oyster mushroom (*P. citrinopileatus*) and pink oyster mushroom (*P. djamor*) were investigated. Waste sawdusts of beech, alder, chestnut and walnut wood were used as substrate. After sterilization of sawdusts, %3 mycelium and %1 calcitic lime were added to the sawdusts and placed in the nylon bags. There was only one type of sawdust in each nylon bags. The temperature of the cultivation room was 15±2 ºC, the humidity was 80 - 90%, and ventilation was made at certain intervals. In the study, while the micellization was the fastest in the *P. citrinopileatus* mushroom type grown on the beech sawdust substrate, it was the slowest in the *P. djamor* mushroom type grown on chestnut sawdust substrate. P. djamor, grown on chestnut sawdust, has been the mushroom type generally had the lowest width-length measure. For *P. ostreatus* grown on beech sawdust compost had the highest width-length dimensions. The lowest yield was seen (19.77%) in the *P. djamor* grown on the chestnut sawdust substrate. The highest yield was observed in *P. citrinopileatus* species grown on beech substrate with 31.02%. Following this, *P. ostreatus* grown on beech sawdust substrate was very close to *P. citrinopileatus* with 30.99% yield. The lowest biological activity rate was seen in (38.22%) *P. djamor* which grown on chestnut sawdust substrate. The highest biological activity rate was in *P. citrinopileatus* grown on beech sawdust substrate with 70.93%.

Keywords: *P. ostreatus*, *P. citrinopileatus*, *P. djamor*, physical analysis, wooden substrate, micellization, mushroom quality and yield, biological activity

1. Introduction

As known that *pleurotus* species fall into the category of non-wood forest products. Although there are about 40 species, 3 important species have been studied in this study (Jose and Janardhanan 2001). Oyster mushrooms are formed by decomposing lignocellulosic composts thanks to their enzymes (Zadrazil, 1978). Due to its easy breeding techniques and wide adaptability, *P. ostreatus* has an important role in recycling organic waste (Das and Mukherjee, 2007). Besides, they do not require environmental control and can be grown simply and cheaply (Josiane et al., 2018).

Oyster mushroom that is grown by imitating natural conditions has an important place in the country's economy (Josiane et al., 2018). Increasing population and diversifying agro-industrial wastes reach large volumes and cause environmental problems as well as commercial exploitation. These wastes are sometimes left in the field, and sometimes they are desired to be eliminated by burning. However, incinerated wastes return to the atmosphere as carbon dioxide, which causes the release of greenhouse gases that cause global warming. *Pleurotus* mushroom comes into play at this point and turns the waste, which is a problem for disposal, into three main outputs, making it beneficial to the environment and living beings. First, useful compost is created by using lignocellulosic waste. As the second output; A value-added product with very high nutritional value is obtained from composts. As the third output; Composed composts after mushroom production are used as animal feed or fertilizer. The composts content can be prepared depend to region. The variety of agricultural or forest waste in its content creates differences in the oyster taste, nutritional value, scent and texture of the oyster.

Today, oyster mushrooms are produced from many different composts and these are compared in terms of their nutritional values (Yıldız et al., 2017a; Yılmaz et al., 2016; Yılmaz et al., 2017).

The main aim of the study is to investigate the usage possibilities of wood production wastes in oyster production. It is also to put forth how which type of waste effects mycelium growth and mushroom quality and compare with each other.

2. Materials and Methods

The project was carried out in the laboratories of the Eastern Black Sea Forestry Research Institute and in the laboratories of the Karadeniz Technical University, Faculty of Forestry, Department of Forest Industry Engineering, Forest Biology and Wood Protection Technology Department.

2.1. Materials

For the preparation of compost, the waste parts of the furniture production woods were used. Waste wood pieces which are consist of alder, walnut, beech, and chestnut tree species were turned into sawdust (Figure 1). Micelles, chemicals and auxiliary elements required were provided from private companies.

2.1.1. Compost Content and Preparation

Wood wastes that were turned into sawdust were sterilized in autoclave at 121 °C for 30 minutes in order to eliminate harmful organisms. After this process, they were allowed to cool. The prepared composts were then filled in polypropylene bags in size of 29 x 45 cm-4 as 1 kg for each variation as seen Figure 1 (Yıldız et al., 2002). Mycelium inoculation was carried out in a sterile cabinet with the help of a sterile spatula by inoculating 3% mycelium to the upper part of the bags. 1% calcitic lime was added to the bags to regulate the Ph balance. The remaining 96% was wood sawdust (Şanlı, 2014). Only one type of wood sawdust was used in each bag. Combination variations with different wood species have not been investigated. The reason composts are of one type is to compare the impact and performance of wood on oyster mushrooms.

Figure 1: Compost materials and bags

2.1.2. Inoculation and Harvesting

Inoculated blogs were followed in the micelle development room where containing 25 ± 2 ^{o}C and 70-80% humidity also suitable light and ventilation. After the mycelium development was completed, 5 cm wide cuts were made on both side surfaces of the bags to encourage mushroom formation. The mushrooms were mostly harvested by cutting them from the surface with a knife when they reached the same size (Figure 2).

Figure 2: Growth mushrooms for measurement and analysis.

2.2. Methods

2.2.1. Measurement and Analysis

2.2.1.1. Mycelium Growth Rate: After the inoculation process, mycelium growth around the bag was daily evaluated.

2.2.1.2. Mushroom Quality Analysis: Cap length, cap width, stipe length and stipe width values were measured on the mushrooms.

2.2.1.3. Total Yield and Biological Efficiency Rate: Oyster mushroom yield was calculated as total fresh weight of mushrooms obtained from 4 flushes in the harvest period (Royse, 1985). Biological efficiencies were calculated as the percentage ratio of the fresh weight of harvested oyster mushrooms over the dry weight of substrates (Chang et al., 1981).

3. Results

3.1. Mycelium Growing Time

P. ostreatus (white oyster mushroom), *P. citrinopileatus* (yellow oyster mushroom), and *P. djamor* (pink oyster mushroom) were cultivated on four different wooden sawdusts (alder, walnut, beech, and chestnut) The mycelium growth duration (day) was presented in Table 1.

Table 1: Mycelium Growth Duration (day) of Cultivated Oyster Mushrooms

Substrates	**Oyster Mushroom (X ± SD)**		
	White Oyster	**Yellow Oyster**	**Pink Oyster**
Alder	18 ± 0.82[a]	16 ± 0.82[a]	20,3 ± 0.96[a]
Walnut	18 ± 0.82[a]	15,5 ± 0.58[b]	20,3 ± 0.96[a]
Beech	16,5 ± 1,29[a]	13 ± 0,82[b]	20 ± 0,82[a]
Chestnut	19,8 ± 1,26[b]	18,3 ± 0,5[c]	21,3 ± 0,96[a]

[a] Means having the same superscript letter(s) are not significantly different ($p>0.05$) by Duncan's multiple range test.

3.2. Mushroom Quality Properties

The mushroom quality properties (cap length, cap width, stipe length, stipe width) of *Pleurotus* types were presented in Table 2.

Table 2: Mushroom Quality Properties of Cultivated Oyster Mushrooms

Substrates		**Cap Length (cm)**		**Cap Width (cm)**		**Stipe Length (cm)**		**Stipe Width (cm)**	
		X	Std	X	Std	X	Std	X	Std
Alder	White	2.20[a]	0.38	8.07[b]	1.36	2.63[a]	0.23	0.49[a]	0.09
	Yellow	2.46[a]	0.56	6.23[a]	2.16	2.67[a]	0.26	0.45[a]	0.19
	Pink	2.44[ab]	0.53	5.67[a]	1.77	2.67[a]	0.18	0.42[ab]	0.09
Walnut	White	2.16[a]	0.70	6.63[a]	1.36	2.63[a]	0.15	0.52[a]	0.11
	Yellow	2.36[a]	0.51	6.06[a]	1.87	2.71[a]	0.27	0.46[a]	0.12
	Pink	2.57[ab]	0.44	5.66[a]	1.71	2.66[a]	0.17	0.48[b]	0.10
Beech	White	2.30[a]	0.78	8.70[b]	1.08	2.61[a]	0.16	0.50[a]	0.16
	Yellow	2.71[a]	0.72	7.07[a]	1.40	2.61[a]	0.20	0.40[a]	0.11
	Pink	2.83[b]	0.71	6.94[a]	1.58	2.73[a]	0.29	0.38[ab]	0.10
Chestnut	White	2.13[a]	0.61	6.49[a]	1.24	2.57[a]	0.18	0.45[a]	0.08
	Yellow	2.16[a]	0.42	5.83[a]	1.08	2.63[a]	0.18	0.41[a]	0.10
	Pink	2.07[a]	0.29	5.33[a]	0.62	2.56[a]	0.10	0.35[a]	0.04

[a] Means having the same superscript letter(s) are not significantly different ($p>0.05$) by Duncan's multiple range test.

3.3. Total Yield

Total yield (%) of the *Pleurotus* types were presented in Table 3.

Table 3: Total Yield (%) of Cultivated Oyster Mushrooms

Substrates	**Oyster Mushrooms (X ± SD)**		
	White Oyster	**Yellow Oyster**	**Pink Oyster**
Alder	25,04 ± 1,68[a]	25,15 ± 3,74[ab]	22,73 ± 1,26[b]
Walnut	22,04 ± 4,19[a]	28,29 ± 2,29[bc]	21,44 ± 1,9[ab]
Beech	30,99 ± 3,88[b]	31,02 ± 3,55[c]	28,81 ± 2,34[c]
Chestnut	21,74 ± 1,07[a]	21,42 ± 1,09[a]	19,77 ± 1,07[a]

[a] Means having the same superscript letter(s) are not significantly different ($p>0.05$) by Duncan's multiple range test.

3.4. Biological Efficiency

Biological efficiency (%) of *Pleurotus* types were presented in Table 4.

Table 4: Biological efficiency (%) of Cultivated Oyster Mushrooms

Substrates	Oyster Mushroom (X ± SD)		
	White Oyster	Yellow Oyster	Pink Oyster
Alder	53,75 ± 2,29[b]	58,72 ± 5,39[b]	49,45 ± 3,42[c]
Walnut	54,65 ± 8,38[b]	62,04 ± 4,07[b]	44,75 ± 2,31[b]
Beech	61,16 ± 5,32[b]	70,93 ± 7,04[c]	66,57 ± 1,93[d]
Chestnut	42,50 ± 2,16[a]	41,60 ± 2,32[a]	38,22 ± 2,16[a]

[a] Means having the same superscript letter(s) are not significantly different (p>0.05) by Duncan's multiple range test.

4. Discussion

4.1. Mycelium Growing Time

In the study, when considering the duration for the mycelium to spread out to the bag, it was determined that *P. citrinopileatus* growing on beech sawdust completed the development within 13 ± 0,82 days, as earliest. *P. djamor* mushroom grown in chestnut sawdust was also completed its mycellium development with 21,3 ± 0,96 days, as latest. (Table 1). Küçükomuzlu and Pekşen (2005) reported that *Pleurotus* spp. produced from straw and bran compost have showed the fastest mycelium development with 39.50 days. In another study, the mycelium development period for *P. ostreatus* was reported as between 28-36 days (Upadyay and Vijay, 1991). In another study, three types of *Pleurotus; P. sajor-caju, P. platypus* and *P. citrinopileatus* mushrooms were grown on a variety of agricultural wastes, such as rice straw, corn stalk, sugar cane pulp, coconut fiber and mixtures of these wastes. The beginning of primordium was observed 22-27th days (Ragunathan et al., 1996). Ragunathanand and Swaminathan (2003), in their similar study, cultivated three species of *Pleurotus*; *P. sajor-caju*, *P. platypus* and *P. citrinopileatus*, on different agricultural wastes (cotton stalk, coconut fiber, sorghum stems and mixtures of these wastes). Primordium beginning was observed between 21 and 30 days. The results of the cultivation of *P. djamor*, *P. ostreatus*, and *P. pulmonarius* species on coffee waste and wheat straw are scrutinized. Primordium growing time was given as 11-12 days in the wheat straw substrate for *P. djamor* at the earliest and 16-32 days for *P. pulmonarius* mushroom at the latest. The same values varied between 13 and 31 days in coffee waste (Salmones et al., 2005). In another study, according to the growing substrate and mushroom species, the mycelium growing time is specified between 2-8 weeks by Oei (1991). In a study, mycelium growth rates of substrates inoculated with five different *Pleurotus* species were compared after 30 days. The lowest rate of development was observed in *P. djamor* mushroom (Kalyoncu and Kalmış, 2007). The study was accordance with literature. Indeed, the shorter mycelium growing time was determined in this study compared to the literature. This situation can be attributed to the amount of substrates and type. In the study, the most suitable sawdust for oyster production was the sawdust obtained from beech wood. Chestnut wood sawdust were the substrate where the minimum mycelium development was obtained. Chestnut tree's natural strength and being antifungal can be associated with this result.

4.2. Mushroom Quality Properties

As seen Table 2, the shortest cap length was found in *P. djamor* mushroom growing in chestnut sawdust compost; The longest cap length was obtained from *P. djamor* mushroom grown in beech sawdust compost. Considering the cap width values, the shortest cap width in *P. djamor* mushroom growing in chestnut sawdust compost; the largest cap width value was obtained in *P. ostreatus* mushroom growing in beech sawdust compost. Considering the stipe length values, the shortest stipe length was seen in *P. djamor* mushroom grown in chestnut sawdust compost; The longest stipe length value was obtained from the *P. djamor* mushroom grown in beech sawdust compost. Considering the stipe width values, the smallest stipe width was seen in *P. djamor* mushroom grown in chestnut sawdust compost; the largest stipe width value was obtained from the *P. ostreatus* mushroom grown in walnut sawdust compost. *P. djamor* (pink oyster) grown on chestnut sawdust stands out with the lowest quality in general. *P. ostreatus* (white oyster) grown in beech sawdust compost is the best quality mushroom among the produced mushrooms. In a study, it was reported that the *P. citrinopileatus* has the largest cap (10,02 cm) and the longest stipe (5,42 cm) among *P. sajor-caju, P. florida, P. eous, P. citrinopileatus, P. fossulatus, P. flabellatus, P. platypus, P. ostreatus, H. ulmarius* mushroom species. *P. ostreatus* took the second place in terms of cap size (9,26 cm) and stipe length (3,20 cm) at the same study. Moreover, *P. ostreatus* (1,73 cm) and *P. citrinopileatus* (1,47 cm) had the thickest stipe in the reference study.

4.3. Total Yield

According to the results of the study, the lowest yield was seen in *P. djamor* mushroom grown in chestnut wood sawdust with 19.77%. The highest yield was obtained from *P. citrinopileatus* grown in beech sawdust with 31.02%. Following that, total yield of *P. ostreatus* mushroom grown in beech sawdust was very close to *P. citrinopileatus* with 30.99% (Table 3). *Pleurotus* spp, is one of the fungi that causes white rot in wood. Beech is one of the most suitable trees for producing mushroom, which is not resistant to fungal rot. In a study, beech, oak, pine, fir and hornbeam trees were selected to investigate rot fungi in the wood. The tree species most exposed to rot in the study was beech (Sertkaya et al., 2017). In another study, *P. ostreatus* gave the highest yield at the first measurement compared to other fungal species (Zhai and Han, 2018). In another study, *pleurotus* species were grown on cotton stipes. Yield was maximum in *P. citrinopileatus* mushrooms (Ragunathanand and Swaminathan, 2003). When the study is compared with the literature, it is seen that the results are in accordance with the literature. Considering the mushrooms and yield results in the study, the results of *P. ostreatus* and *P. citrinopileatus* show similarity with other studies.

4.4. Biological Efficiency

According to the results of the study, the lowest biological efficiency rate was found in *P. djamor* mushroom growing in chestnut wood sawdust with 38.22%. The highest biological activity rate was found in *P. citrinopileatus* mushroom growing in beech wood sawdust with 70.93% (Table 4). In a study, three species of *Pleurotus*, *P. sajor-caju, P. platypus*, and *P. citrinopileatus* mushrooms were grown on various agricultural wastes such as rice straw, corn stalk, sugar cane pulp, coconut fiber and a mixture of these wastes. Biological activity varied between 25.18% and 38.63% (Ragunathan et al., 1996). In another study, three species of *Pleurotus, P. sajor-caju, P. platypus* and *P. citrinopileatus* were grown on different agricultural wastes (cotton stalk, coconut fiber, sorghum stems and mixtures of these wastes). Biological activity ranged from 26.11% to 41.42% (Ragunathanand and Swaminathan, 2003). In a different study, oyster mushroom that produced from coffee waste and wheat straw have been studied. Salmones et al. (2005), found the biological efficiency rate between 30.5 and 80.5%. Industrial paper waste was investigated in the production of *P. citrinopileatus* mushrooms. Biological efficiency ranged from 3.3% to 94.5% (Kulshreshtha et al., 2013). As seen in the studies, the biological efficiency rate varies between a wide scale depending on the type of mushroom to be produced and the growing substrate. Therefore, it is seen that the results of this study also support the literature studies.

5. Conclusion

In this study, physical properties and quality analyses of the oyster mushrooms species produced in the different composts and under the specified conditions were investigated. . When oyster mushrooms want to be consumed as food, the cap part is especially consumed. It is known that the stipe part is not consumed much in general. Considered the size of the cap, the white oyster grown on beech compost can be recommended as food.

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