Turkish Journal of Biology

Volume 33 | Number 2 Article 12

1-1-2009

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Turk J Biol
33 (2009) 171-179

doi:10.3906/biy-0804-2

A Comparative Study on *Pleurotus ostreatus* (Jacq.) P.Kumm. Cultivated on Different Agricultural Lignocellulosic Wastes

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Received: 01.04.2008

Abstract: For the cultivation of *Pleurotus ostreatus* (Jacq.) P.Kumm. wheat stalk (WS), cotton stalk (CS), millet stalk (MS), and soybean stalk (SS) were used as the main material and oven-dried lentil straw (LS) was used as an additive material 100:10, 100:15, 100:20 w:w in weight for 100 g of main material (70% moisture). The shortest mycelium growing time (MGT) was 10.2 days, on the SS, while the longest was 18.8 days, on the CS. The shortest first harvest time (FHT) was 30 days, on SS + LS (90:10; w:w), and the longest was 46.4 days, on CS + LS (100:20; w:w). The shortest total harvest time (THT) was as 62.6 days, on SS + LS (100:20; w:w), and the longest was 83.8 days, on CS + LS (100:10; w:w) culture medium. The highest total harvest amount was 49.9 g, from SS + LS (100:20; w:w), while the lowest was 14.3 g, obtained from CS. The highest biologic efficiency degree (BED) and biologic conversion ratio (BCR) values were obtained from SS + LS (100:20; w:w), 166.18% and 16.53%, respectively. The highest first harvest amount percentage (FHAP) was on WS + LS (100:15; w:w), 62.83%; the highest second harvest amount percentage (SHAP) was obtained from SS + LS (100:15; w:w) compost medium, 38.60%; and the highest third harvest amount percentage (THAP) value was 26.92%, on the CS culture medium.

Key Words: *Pleurotus ostreatus*, biologic efficiency degree, biologic conversion ratio, mushroom yield, mycelium growing time, primordial formation time

Farklı Lignoselülozik Tarımsal Artıklar Üzerinde Kültüre Alınan *Pleurotus ostreatus* (Jacq.) P.Kumm. Üzerinde Karşılaştırmalı Bir Çalışma

Özet: Bu çalışmada; *P. ostreatus* (Jacq.) P.Kumm. kültüründe, ham materyal olarak; buğday, pamuk, darı ve soya sapı, katkı materyali olarak da mercimek samanı kullanılmıştır. Her deney grubu için ayrı ayrı, yaklaşık olarak % 70 nem içeren kompostun 100 g'ına 10, 15 ve 20 g fırın kuru mercimek samanı katkı maddesi olarak ilave edilmiştir. Misel gelişim süresi en hızlı 10,2 gün olarak saf soya sapı kültür ortamında, en yavaş ise saf pamuk sapında 18,8 gün olarak belirlenmiştir. Birinci hasat süresi en kısa 30 gün ile soya sapına 10 g mercimek samanı katkılı kültür ortamında, en uzun ise 46,4 gün ile pamuk sapı kültür ortamına 20 g mercimek samanı katkılı kültür ortamında belirlenmiştir. Üçüncü hasat en kısa 62,6 gün ile 20 g mercimek samanı katkılı soya sapında, en uzun süre ise 83,8 günde pamuk sapına ilave edilen 10 g mercimek samanı katkılı kültür ortamında belirlenmiştir. Toplam ürün verim mikarı en fazla soya sapına ilave edilen 20 g mercimek samanı katkılı ortamdan 49,9 g olarak, en az ise 14,3 g olarak saf pamuk sapından elde edilmiştir. En yüksek biyolojik etkinlik derecesi ve biyolojik dönüşüm oranı, soya sapına 20 g mercimek samanı katkılı ortamlarda sırasıyla; % 166,18 ve % 16,53 olarak elde edilirken, en düşük oranları ise sırasıyla; % 46,61 ve % 4,04 olarak saf pamuk sapı kültür ortamından elde edilmiştir. Toplam hasatta elde edilen ürünün, hasat evrelerindeki % oransal dağılımı; en yüksek oranda birinci hasatta buğday sapına 15 g mercimek samanı katkılı ortamdan % 62,83 olarak, ikinci hasatta soya sapına 15 g mercimek samanı katkılı kompost ortamından % 38,60 olarak, üçüncü hasatta da saf pamuk sapı kompost ortamından % 26,92 olarak bulunmuştur.

Anahtar Sözcükler: *Pleurotus ostreatus*, biyolojik etkinlik derecesi, biyolojik dönüşüm oranı, mantar verimi, misel gelişim zamanı, primordiyum oluşum zamanı

Introduction

There are at least 12,000 species of fungi that can be considered mushrooms, with at least 2000 species showing various degrees of edibility (1). Furthermore, over 200 species have been collected from the wild and used for various traditional medical purposes, mostly in the Far East. About 35 mushroom species have been cultivated commercially, and, of these, around 20 are cultivated on an industrial scale. The mushroom cultivated most worldwide is *Agaricus bisporus* (button mushroom), followed by *Lentinus edodes* (shiitake), *Pleurotus* spp. (oyster mushrooms), *Auricula auricula* (wood ear mushroom), *Flammulina velutipes* (winter mushroom), and *Volvariella volvacea* (straw mushroom) (1). Mushrooms have the ability to degrade lignocellulosic substrates and can be produced on natural materials from agriculture, woodland, animal husbandry, and manufacturing industries (2), which are often landfilled or burned in the field at great cost to the environment (3). However, mushroom production generates an enormous amount of used "spent" substrate, which might also be a source of environmental contamination. Currently, several uses for spent substrate are being evaluated and some of them have already been established (2). The commercial benefits of this production system include lower cost, low energy requirements, automation, low labour demand, lack of down-time, light and cheap transport, low contamination risk, and long shelf-life. The Mycocell system allows the successful culture of exotic mushrooms such as *L. edodes*, *P. ostreatus*, *P. pulmonarius*, *P. eryngii*, *P. djamor*, *P. cystidiosus*, *Pholiota* sp., *Hypsizygus* sp., *F. velutipes*, *Agrocybe aegerita*, *Ganoderma lucidum*, *Psilocybe* sp., *Grifola frondosa*, *Hericium* sp., and *Auricularia* (4). Spent mushroom substrate has been used as animal feed, since its degradation by the mushroom can improve its nutritional quality (5-8) and digestibility (8-16). Chang found that when maize straw generated after mushroom cultivation was added to the diets of sheep, the weight gain of the sheep increased, as did the efficiency of the straw feed conversion (17). Oyster mushrooms (*Pleurotus* species), the third largest commercially produced mushroom in the world (17), are found growing naturally on rotten wood material. The growing increase in consumption of oyster mushroom is largely due to its taste, and medicinal and nutritional properties (18). *Pleurotus ostreatus*, one of the species produced on the largest scale, is cultivated mainly on sawdust. The unavailability of sawdust and the fact that felling of trees in most regions of the world is prohibited make it imperative that other sources of substrates be utilised for its cultivation. In our region large volumes of unused lignocellulosic by-products can be found. These by-products are left to rot in the field or are disposed of through burning. Cultivation of mushrooms on these by-products may be one of the solutions to transforming these inedible wastes into accepted edible biomass of high market value. The spent substrates from mushroom cultivation can also potentially be used as an animal feed supplement, possibly providing additional animal feed resources (19). This paper reports the effects of the agricultural lignocellulosic wastes wheat stalk (WS), cotton stalk (CS), millet stalk (MS), soybean stalk (SS), and additive material lentil straw (LS) as substrates on the mycelium growing time (MGT), primordial formation time (PFT), first harvest time (FHT), second harvest time (SHT), third harvest time (THT), biologic efficiency degree (BED), biologic conversion ratio (BCR), and fresh mushroom yield obtained with 100 g of material (70% moisture) at the first, second, third, and total harvest amounts and the percentage of the harvest amounts obtained from the first, second, and third harvests in the total harvest amount of the fruit bodies of *P. ostreatus* harvested from various substrates based on 3 flushes.

Materials and Methods

The main substrates, namely wheat stalk (WS), cotton stalk (CS), millet stalk (MS), and soybean stalk (SS), and the additive material, lentil straw (LS), used in this study were agricultural wastes that are usually burned or left in the field to rot in our region and they were obtained from Dicle University campus. The materials used in this study were analysed for their nitrogen (N) contents. The nitrogen content was determined by the Kjeldahl method and is shown in Table 1.

Table 1. Nitrogen (N) analysis of materials used for *P. ostreatus* cultivation.

Materials	SS	MS	WS	CS	LS
N (%)	0.54	1.31	0.50	0.34	1.48

WS: Wheat stalk, MS: Millet stalk, CS: Cotton stalk, SS: Soybean stalk, LS: Lentil straw.

Mycelium of *P. ostreatus* was obtained from Microbiology Laboratory of Science and Arts Faculty of Dicle University. The mushroom growing process was also accomplished in the Mushroom Culture Room of Science and Arts Faculty of Dicle University in which the temperature, ventilation, and relative humidity could be controlled. In this study, we prepared 4 experiment groups for the culture medium of WS, CS, MS, and SS. For each experimental group there were 4 trial groups: they were control (pure, 100), 100:10, 100:15, and 100:20 w:w in weight of LS per 100 g (70% moisture) of main materials and 5 replications were applied for each growing trial. Establishment of experiment groups is shown in Table 2.

Substrates were moistened with water until 70% moisture content levels were attained and then placed in 2-l glass jars, closed, and sterilized in an autoclave at 121 °C for 30 min. The moisture content of each compost was determined by drying 10 g samples in an oven at 105 °C, and the weight differences between the fresh and dried compost samples were calculated as % moisture content. After cooling the substrates to room temperature, they were inoculated by spreading spawn on the surface of the substrate with a weight percentage of about 4% of the wet weight of compost. Inoculated glass jars were brought to the mushroom culture room and they were incubated at 25 ± 1 °C under dark conditions. After the substrates were completely colonized by the mycelium the jars were unfolded for cropping and incubated at 12 ± 1 °C and 80%-90% relative humidity was provided by water spraying twice a day until fruit bodies developed. The room was ventilated with an air cooler for 4 to 5 h each day to provide aeration and illuminated 10-12 h/day until primordia formed. Ecological conditions during the harvesting period were maintained the same as for the primordium formation period. The bioconversion efficiency was defined as the grams of dry mushrooms produced per 100 g of dry substrate used. The biological efficiencies was defined as the percentage of the fresh weight of harvested mushrooms over the dry weight of substrate as explained by Zervakis and Balis (20), and Chang et al. (21) have defined the term "biological efficiency" to express the yield of fresh fruit bodies per 100 g dry substrate and some researchers have adopted this definition to evaluate the quality of organic waste as a substrate for mushroom cultivation (22,23). The data obtained from this study were analysed by ANOVA and tests of significance were carried out using Duncan's multiple range tests.

Results and Discussion

Mycelium growing time (MGT), primordial formation time (PFT), first harvest time (FHT), second harvest time (SHT), and third harvest time (THT) of the cultivation of *P. ostreatus* are given in Table 3. The values showed significant differences ($P \leq 0.05$). MGT varied from 10.2 to 18.8 days. The shortest MGT was 10.2 days, with the SS, and the longest MGT was 18.8 days, with the CS substrate. The shortest MGT was in conformity with previous findings (24-27). Primordial formation continued from 20 to 34.2 days. The first PFT was observed on pure SS at 20 days and the last was observed on CS + LS (100:20; w:w) at 34.2 days. The first PFT findings are in good agreement with previous studies (26,28,29). First harvest time continued from 30 to 46.4 days. The first FHT was at 30 days on SS + LS (100:10; w:w) and the last was at 46.4 days on CS + LS (100:20; w:w). The FHT values obtained from the study are in accordance with Zadrazil (30), Yıldız and Demir (25), and Baysal et al. (26). The second harvest time was at 45.6-66 days. The most rapid SHT was observed on SS + LS

Table 2. Establishment of 4 experiment groups.

First	Second	Third	Fourth
WS (100)	MS (100)	CS (100)	SS (100)
WS + LS (100:10; w:w)	MS + LS (100:10; w:w)	CS + LS (100:10; w:w)	SS + LS (100:10; w:w)
WS + LS (100:15; w:w)	MS + LS (100:15; w:w)	CS + LS (100:15; w:w)	SS + LS (100:15; w:w)
WS + LS (100:20; w:w)	MS + LS (100:20; w:w)	CS + LS (100:20; w:w)	SS + LS (90:20; w:w)

WS: Wheat stalk, MS: Millet stalk, CS: Cotton stalk, SS: Soybean stalk, LS: Lentil straw.

Table 3. Effect of different lignocellulosic wastes and different doses of additive material on developing periods of *P. ostreatus* (day).*

Materials	MGT	PFT	FHT	SHT	THT
WS (100)	$15.0 \pm 5.6^{e}_{x}$	$25.4 \pm 3.9^{d}_{x}$	35.8 ± 5.3^{c}	58.2 ± 3.4^{b}	$82.4 \pm 3.2^{a}_{x}$
WS + LS (100:10; w:w)	$13.8 \pm 3.0^{e}_{x}$	$29.0 \pm 6.3^{c}_{x}$	39.2 ± 6.4^{c}	51.4 ± 7.4^{b}	$77.0 \pm 8.0^{a}_{x}$
WS + LS (100:15; w:w)	$11.6 \pm 0.8^{e}_{x}$	$25.4 \pm 2.0^{d}_{x}$	$36.0 \pm 2.0^{c}_{x}$	45.8 ± 3.3^{by}	$69.8 \pm 1.0^{a}_{x}$
WS + LS (100:20; w:w)	$12.8 \pm 3.4^{d}_{x}$	$27.4 \pm 5.9^{c}_{x}$	$36.4 \pm 7.7^{c}_{x}$	$56.0 \pm 6.2^{b}_{yt}$	$72.8 \pm 2.2^{a}_{x}$
MS (100)	$11.0 \pm 1.2^{e}_{x}$	$27.2 \pm 4.2^{d}_{x}$	$37.2 \pm 4.8^{c}_{x}$	$60.8 \pm 5.4^{b}_{yt}$	$79.4 \pm 3.9^{a}_{y}$
MS + LS (100:10; w:w)	$13.8 \pm 3.1^{e}_{x}$	$25.4 \pm 4.7^{d}_{x}$	$40.4 \pm 1.8^{c}_{xy}$	$64.0 \pm 4.5^{b}_{yt}$	$83.8 \pm 2.2^{a}_{xy}$
MS + LS (100:15; w:w)	$11.4 \pm 1.1^{e}_{x}$	$25.2 \pm 4.9^{c}_{x}$	$34.2 \pm 5.2^{c}_{xy}$	$54.2 \pm 5.9^{b}_{xt}$	$78.6 \pm 1.9^{a}_{y}$
MS + LS (100:20; w:w)	$12.2 \pm 2.1^{e}_{x}$	$22.4 \pm 1.9^{d}_{x}$	$34.0 \pm 1.5^{c}_{xy}$	$52.0 \pm 1.5^{b}_{t}$	$80.8 \pm 1.9^{a}_{xy}$
CS (100)	$18.8 \pm 8.6^{d}_{x}$	$33.2 \pm 9.6^{cd}_{x}$	$46.4 \pm 9.6^{c}_{xy}$	$66.0 \pm 6.5^{b}_{y}$	$83.8 \pm 2.5^{a}_{xy}$
CS + LS (100:10; w:w)	$17.6 \pm 9.4^{d}_{x}$	$31.4 \pm 9.2^{cd}_{x}$	$42.2 \pm 10.1^{c}_{xy}$	$62.6 \pm 9.8^{b}_{y}$	$75.8 \pm 6.2^{a}_{xy}$
CS + LS (100:15; w:w)	$12.6 \pm 5.2^{d}_{x}$	$28.8 \pm 7.9^{c}_{x}$	$38.4 \pm 9.30^{c}_{x}$	$57.8 \pm 7.6^{b}_{y}$	$81.2 \pm 2.5^{a}_{xy}$
CS + LS (100:20; w:w)	$17.2 \pm 8.8^{cd}_{x}$	$34.2 \pm 13.7^{c}_{y}$	$45.8 \pm 15.7^{c}_{x}$	$57.2 \pm 6.6^{b}_{y}$	$76.6 \pm 7.5^{a}_{x}$
SS (100)	$10.2 \pm 0.4^{e}_{x}$	$20.0 \pm 1.7^{d}_{x}$	$30.4 \pm 2.60^{c}_{x}$	$46.2 \pm 2.1^{b}_{x}$	$64.2 \pm 2.9^{a}_{t}$
SS + LS (100:10; w:w)	$10.4 \pm 0.5^{e}_{x}$	$21.0 \pm 2.0^{d}_{x}$	$30.0 \pm 2.80^{c}_{x}$	$46.6 \pm 2.5^{b}_{x}$	$64.8 \pm 5.6^{a}_{t}$
SS + LS (100:15; w:w)	$11.0 \pm 1.4^{e}_{x}$	$21.0 \pm 1.8^{d}_{x}$	$29.6 \pm 1.60^{c}_{x}$	$45.6 \pm 3.1^{b}_{x}$	$64.0 \pm 3.3^{a}_{t}$
SS + LS (100:20; w:w)	$11.6 \pm 0.8^{e}_{x}$	$22.2 \pm 0.8^{d}_{x}$	$30.6 \pm 2.30^{c}_{x}$	$46.4 \pm 2.6^{b}_{x}$	$62.6 \pm 2.4^{a}_{t}$

* Small letters written on the averages show the row and the small letters written below the averages show the column comparison. Different letters written in the row and column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. MGT: Mycelium growing time, PFT: Primordium formation time, FHT: first harvest time, SHT: Second harvest time, THT: third harvest time, WS: Wheat stalk, MS: Millet stalk, CS: Cotton stalk, SS: Soybean stalk, LS: Lentil straw.

(100:15; w:w), at 45.6 days, and the slowest was observed on CS culture medium, at 66 days. The most rapid SHT results are in conformity with the other previous studies carried out by Zadrazil (30) and Klibansky et al. (31). Third harvest time values were 62.6-83.8 days. The shortest THT was 62.6 days, on SS + LS (100:20; w:w), and the longest was 83.8 days, on CS + LS (100:10; w:w). The shortest THT obtained from this study was in good agreement with previous studies carried out by Zadrazil (30) and Klibansky et al. (31). The differences between the MGT, PFT, FHT, SHT, and THT values obtained from the different culture media in this study may have resulted from the N contents of the materials as mentioned previously (32-34). Olivier (35) reported that N amount of substrates affects the mycelium growing, primordium formation, and therefore harvest time of cultivated mushrooms. These reports (32-34) are in accordance with our study.

The fresh mushroom yields obtained with 100 g of material at the first, second, third, and total harvests were determined and are shown in Table 4. There are significant differences ($P \leq 0.05$) between the values obtained. The highest first, second, third, and total harvest were obtained from SS + LS (100:20; w:w), as 24.5 g; SS + LS (100:15; w:w), as 17.6 g; SS + LS (100:20; w:w), as 9.7 g; and SS + LS (100:20; w:w), as 49.9 g, respectively. The lowest first, second, third, and total harvest were obtained from CS (100), as 7.3 g; CS (100), as 3.0 g; CS + LS (100:10; w:w), as 2.1 g; and CS (100), as 14.3 g, respectively.

As explained above, the culture media in which SS was used as a main material gave the highest yield and CS culture media gave the lowest yield in the first, second, third, and total harvest. These findings may have resulted from the N contents of the substrates; SS contained higher N than CS did. These findings are in accordance with the study by Olivier (35), which stated that the highest yield can be obtained from the substrate containing 0.7%-0.9% N in dried weight. In the present study adding nitrogen-rich additive material to raw

Table 4. First, second, third, and total harvest amounts (g) of *P. ostreatus* cultivated on different lignocellulosic wastes (per 100 g of substrates 70% moisture).*

Materials	First harvest	Second harvest	Third harvest	Total harvest
WS (100)	$10.1 \pm 3.8^{b}_{xt}$	$4.2 \pm 1.9^{c}_{x\,z}$	$3.5 \pm 1.0^{c}_{x}$	$17.9 \pm 6.3^{a}_{yz}$
WS + LS (100:10; w:w)	$13.1 \pm 4.2^{b}_{x}$	$5.1 \pm 2.3^{c}_{x\,z}$	$3.9 \pm 0.9^{c}_{x}$	$22.3 \pm 6.9^{a}_{xyz}$
WS + LS (100:15; w:w)	$14.1 \pm 6.3^{b}_{x}$	$4.2 \pm 0.6^{c}_{x\,z}$	$3.8 \pm 1.3^{c}_{x}$	$22.1 \pm 7.9^{a}_{xyz}$
WS + LS (100:20; w:w)	$14.6 \pm 4.8^{b}_{x}$	$8.1 \pm 3.3^{c}_{x}$	$4.7 \pm 1.4^{c}_{xw}$	$27.5 \pm 9.4^{a}_{xz}$
MS (100)	$12.9 \pm 4.2^{b}_{yx}$	$6.1 \pm 3.1^{c}_{x\,z}$	$3.7 \pm 1.0^{c}_{x}$	$22.7 \pm 7.0^{a}_{xyz}$
MS + LS (100:10; w:w)	$16.8 \pm 1.3^{b}_{y}$	$7.4 \pm 1.4^{c}_{x\,y}$	$7.7 \pm 2.5^{c}_{yw}$	$32.0 \pm 3.3^{a}_{xz}$
MS + LS (100:15; w:w)	$14.1 \pm 2.1^{b}_{y}$	$8.1 \pm 1.2^{c}_{y}$	$5.2 \pm 0.7^{d}_{y}$	$27.5 \pm 1.9^{a}_{xz}$
MS + LS (100:20; w:w)	$15.2 \pm 3.7^{b}_{y}$	$7.9 \pm 2.5^{c}_{y}$	$4.9 \pm 1.7^{c}_{y}$	$28.1 \pm 6.2^{a}_{xz}$
CS (100)	$7.3 \pm 1.6^{b}_{zt}$	$3.0 \pm 1.3^{c}_{z}$	$3.9 \pm 2.3^{c}_{y}$	$14.3 \pm 2.4^{c}_{y}$
CS + LS (100:10; w:w)	$8.6 \pm 0.7^{b}_{z}$	$4.1 \pm 1.0^{c}_{zt}$	$2.1 \pm 1.2^{d}_{x}$	$14.9 \pm 2.0^{a}_{y}$
CS + LS (100:15; w:w)	$8.8 \pm 1.5^{b}_{z}$	$4.7 \pm 0.7^{c}_{zt}$	$2.8 \pm 1.0^{d}_{x}$	$16.4 \pm 1.3^{a}_{y}$
CS + LS (100:20; w:w)	$8.1 \pm 2.2^{b}_{zt}$	4.1 ± 1.3^{c}	$_{zt}2.8 \pm 1.5^{c}_{x}$	$15.2 \pm 4.0^{a}_{yz}$
SS (100)	$17.3 \pm 6.8^{b}_{wx}$	$9.5 \pm 4.4^{bc}_{t}$	$4.5 \pm 2.3^{c}_{w}$	$31.5 \pm 12.8^{a}_{txz}$
SS + LS (100:10; w:w)	$24.1 \pm 2.9^{b}_{w}$	$14.3 \pm 1.6^{c}_{wt}$	$6.3 \pm 1.9^{d}_{w}$	$44.8 \pm 3.7^{a}_{wt}$
SS + LS (100:15; w:w)	$20.6 \pm 3.3^{b}_{w}$	17.6 ± 3.3^{bc}	$6.6 \pm 1.0^{d}_{w}$	$44.9 \pm 4.7^{a}_{wt}$
SS + LS (100:20; w:w)	$24.5 \pm 1.1^{b}_{w}$	$15.5 \pm 1.1^{c}_{w}$	$9.7 \pm 0.8^{d}_{t}$	$49.9 \pm 2.8^{a}_{w}$

* Small letters written on the averages show the row and the small letters written below the averages show the column comparison. Different letters written in the row and column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. WS: Wheat stalk, MS: Millet stalk, CS: Cotton stalk, SS: Soybean stalk, LS: Lentil straw.

materials generally increased the mushroom yield, as indicated previously (25,26,30-33). We obtained different yields from each different culture medium. The use of varied substrate media for the cultivation of mushrooms may have caused different yields because of biological and chemical differences between the substrate media as indicated in the literature (25,26,30-33). Therefore, the SS substrate medium is found the most convenient culture medium for productivity of *P. ostreatus* in our study. Additionally, the total harvest amount of the SS + LS (100:20; w:w) (49.9 g) is the highest when we compare with the other researchers' findings (25,27,34-35). In the present study, biologic efficiency degree (BED) and biologic conversion ratio (BCR) values indicate that there is a correct balance between BED and BCR. The BED and BCR of the fruit bodies of *P. ostreatus* harvested from various substrates based on 3 flushes are shown in Tables 5-8. There are significant differences ($P \leq 0.05$) between the values obtained from the study. When all the experimental groups were evaluated the highest BED and BCR were obtained from SS + LS (100:20; w:w), 166.18% and 16.53%; while the lowest values were 46.61% and 4.04%, from CS culture medium. This 166.18% BED value was the highest when compared to the BED findings reported by other researchers: Klinbasky 97.8% (31) and Royse 79% (36). According the results obtained from this study, the differences of substrates type caused differences in BED and BCR. SS produced a higher BED and BCR than did WS, MS, and CS. These findings may have resulted from the biological, chemical, and physical differences between the substrate media and genotype of the cultured mushroom as stated by Laborde et al. (37), Sangwan and Saini (38), Yıldız and Demir (25), Ragunathan and Swaminathan (32), and Shah et al. (27).

As shown in Table 9, we calculated the percentage of the harvest amounts obtained from the first (FHAP), second (SHAP), and third (THAP) harvest in the total harvest amount. There are significant differences ($P \leq 0.05$) between the FHAP, SHAP, and THAP values

Table 5. Biologic efficiency degree (BED) and biologic conversion ratio (BCR) of *P. ostreatus* cultivated on wheat stalk (WS) culture media.*

Materials	Biologic efficiency degree (%)	Biologic conversion ratio (%)
WS (100)	59.22 ± 0.75[c]	5.03 ± 0.07[c]
WS + LS (100:10; w:w)	73.86 ± 0.53[b]	7.24 ± 0.30[b]
WS + LS (100:15; w:w)	73.30 ± 0.32[b]	7.10 ± 0.55[b]
WS + LS (100:20; w:w)	91.47 ± 0.41[a]	9.17 ± 0.21[a]

* Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. WS: Wheat stalk, LS: Lentil straw.

Table 6. Biologic efficiency degree (BED) and biologic conversion ratio (BCR) of *P. ostreatus* cultivated on millet stalk (MS) culture media.*

Materials	Biologic efficiency degree (%)	Biologic conversion ratio (%)
MS (100)	75.06 ± 0.36[d]	6.95 ± 0.29[c]
MS + LS (100:10; w:w)	105.61 ± 0.65[a]	10.16 ± 0.14[a]
MS + LS (100:15; w:w)	90.97 ± 0.75[c]	8.95 ± 0.55[b]
MS + LS (100:20; w:w)	93.29 ± 0.33[b]	9.30 ± 0.71[b]

* Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. MS: Millet stalk, LS: Lentil straw.

Table 7. Biologic efficiency degree (BED) and biologic conversion ratio (BCR) of *P. ostreatus* cultivated on cotton stalk (CS) culture media.*

Materials	Biologic efficiency degree (%)	Biologic conversion ratio (%)
CS (100)	46.61 ± 0.84[d]	4.04 ± 0.30[b]
CS + LS (100:10; w:w)	49.08 ± 0.37[c]	4.24 ± 0.21[b]
CS + LS (100:15; w:w)	53.82 ± 0.51[a]	5.42 ± 0.37[a]
CS + LS (100:20; w:w)	52.14 ± 0.84[b]	5.19 ± 0.51[a]

* Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. CS: Cotton stalk, LS: Lentil straw.

Table 8. Biologic efficiency degree (BED) and biologic conversion ratio (BCR) of *P. ostreatus* cultivated on soybean stalk (SS) culture media.*

Materials	Biologic efficiency degree (%)	Biologic conversion ratio (%)
SS (100)	105.15 ± 0.26[c]	9.29 ± 0.69[c]
SS + LS (100:10; w:w)	149.10 ± 0.30[b]	15.08 ± 0.50[b]
SS + LS (100:15; w:w)	148.51 ± 0.83[b]	15.20 ± 0.37[b]
SS + LS (100:20; w:w)	166.18 ± 0.48[a]	16.53 ± 0.52[a]

* Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. SS; Soybean stalk, LS: Lentil straw.

Table 9. Percentage of the first, second, and third harvests in the total harvest amount of *P. ostreatus* cultivated on different lignocellulosic wastes.*

Materials	FHAP (%)	SHAP (%)	THAP (%)
WS (100)	$56.26 \pm 0.82^{a}_{x}$	24.36 ± 0.79^{b}x	$20.52 \pm 0.73^{c}_{x}$
WS + LS (100:10; w:w)	$58.41 \pm 1.10^{a}_{y}$	$22.49 \pm 0.98^{b}_{x}$	$17.49 \pm 1.08^{c}_{y}$
WS + LS (100:15; w:w)	$62.83 \pm 0.24^{a}_{z}$	$18.98 \pm 0.36^{b}_{y}$	$18.06 \pm 0.43^{c}_{y}$
WS + LS (100:20; w:w)	$53.07 \pm 0.16^{a}_{t}$	$29.06 \pm 0.65^{b}_{z}$	$18.25 \pm 0.26^{c}_{y}$
MS (100)	$56.28 \pm 0.66^{a}_{x}$	$27.03 \pm 0.64^{b}_{t}$	$17.08 \pm 0.38^{c}_{y}$
MS + LS (100:10; w:w)	$52.49 \pm 0.43^{a}_{t}$	$23.98 \pm 0.66^{b}_{x}$	$24.04 \pm 0.75^{c}_{z}$
MS + LS (100:15; w:w)	$51.95 \pm 0.34^{a}_{t}$	$28.95 \pm 0.61^{b}_{t}$	$19.25 \pm 0.66^{c}_{x}$
MS + LS (100:20; w:w)	$53.90 \pm 0.39^{a}_{t}$	$27.94 \pm 0.51^{b}_{t}$	$17.83 \pm 0.55^{c}_{y}$
CS (100)	$52.11 \pm 0.26^{a}_{t}$	$20.91 \pm 0.56^{c}_{w}$	$26.92 \pm 1.30^{b}_{t}$
CS + LS (100:10; w:w)	$58.84 \pm 0.44^{a}_{y}$	$26.93 \pm 0.32^{b}_{t}$	$14.24 \pm 0.30^{c}_{w}$
CS + LS (100:15; w:w)	$55.18 \pm 0.20^{a}_{x}$	$28.21 \pm 0.25^{b}_{t}$	$17.11 \pm 0.50^{c}_{y}$
CS + LS (100:20; w:w)	$55.27 \pm 0.25^{a}_{x}$	$26.83 \pm 0.46^{b}_{t}$	$18.23 \pm 0.37^{c}_{y}$
SS (100)	$56.19 \pm 0.21^{a}_{x}$	$30.35 \pm 0.52^{b}_{t}$	$14.56 \pm 0.34^{c}_{w}$
SS + LS (100:10; w:w)	$54.77 \pm 0.47^{a}_{x}$	$32.01 \pm 0.76^{b}_{t}$	$14.24 \pm 0.30^{c}_{w}$
SS + LS (100:15; w:w)	$47.14 \pm 0.16^{a}_{z}$	$38.60 \pm 0.60^{b}_{t}$	$14.14 \pm 0.46^{c}_{w}$
SS + LS (100:20; w:w)	$49.01 \pm 0.39^{a}_{z}$	$31.13 \pm 0.19^{b}_{t}$	$20.11 \pm 0.14^{c}_{x}$

* Small letters written on the averages show the row and the small letters written below the averages show the column comparison. Different letters written in the row and column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. WS: Wheat stalk, MS: Millet stalk, CS: Cotton stalk, SS: Soybean stalk, LS: Lentil straw. FHAP: First harvest amount percentage, SHAP: Second harvest amount percentage, THAP: Third harvest amount percentage.

obtained from the study. The WS + LS (100:15; w:w) culture medium showed the highest FHAP and the lowest SHAP, and SS + LS (100:15; w:w) showed the highest SHAP and the lowest FHAP and THAP. Additionally, in this study, FHAP ranged from 47.14% to 62.83%. Therefore mushroom cultivators can market at least their 50% of total mushrooms at first harvest and these mushrooms are fresher and stronger in structure than the second and third harvests' mushrooms. This can provide an economical advantage to the mushroom cultivators.

In conclusion, the lignocellulosic agricultural wastes (wheat stalk, cotton stalk, millet stalk, soybean stalk, and lentil straw) used in this study are usually burned or left in the field to rot in our region but can be effectively used for the cultivation of *P. ostreatus*. We recommend SS + LS (100:20; w:w) culture medium to mushroom cultivators for its best yield performance and earliness of fructification. Additionally, cultivation of *P. ostreatus* on agricultural wastes helps in the effective disposal of these materials. This will provide an economical gain and protect the environment while providing a nutritious food source such as mushrooms.

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