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Evaluation of substrate efficacy and supplementation on the growth and productivity of three species of oyster mushrooms

Zeena Salah Al-Jbouri[1*], Majida Hadi Alsaady[1], Ahmed Kareem Abdulrazzaq[2]

[1] Biology Department, College of Science, University of Baghdad, Baghdad, Iraq
[2] Ministry of Agriculture, Plant Protection Directorate, Baghdad, Iraq
* Corresponding author's e-mail: zeenasaljbouri@gmail.com

ABSTRACT

Edible mushrooms, due to their close association with human food, are among the most diverse organisms. These mushrooms, including species such as *Pleurotus* (oyster mushrooms), play an important role in agricultural sustainability. The diversity of substrates used for mushroom cultivation significantly influences growth and yield. This study sought to examine agricultural waste as substrates for cultivating oyster mushrooms (*Pleurotus ostreatus, florida,* and *sapidus*). Investigated the impact of various waste materials on mushroom growth and productivity. The study involved three primary agricultural waste substrates: wheat straw, corncobs, supplemented with molasses, and cowpea waste. All treatments also included wheat bran and $CaCO_3$. Several parameters were measured during the cultivation process, including linear mycelia growth rate, time to complete growth in production bags, pinhead formation, production yield, and biological efficiency. The results showed that *P. sapidus* exhibited the fastest linear mycelia growth on the treatment with corncobs supplemented with cowpea (0.796 cm/day). *P. florida* was the fastest to colonize the substrate, completing growth in 33 days when wheat straw was supplemented with cowpea. *P. florida* also showed the quickest pinhead formation, appearing in just 2 days on the wheat straw and cowpea treatment, and on corncobs supplemented with molasses. In terms of yield, *P. florida* produced the highest yield (256 g/bag) on wheat straw and corncobs supplemented with cowpea. The maximum biological efficiency for *P. florida* was 67.5% with wheat straw alone and 61.9% when combining wheat straw with corncobs and cowpea supplements. The final conclusion is combination of wheat straw and corncobs supplemented with cowpea significantly enhanced both growth and yield of oyster mushrooms, particularly *P. florida*. These findings suggest that agricultural waste, when properly supplemented, can be an effective substrate for mushroom cultivation, promoting better productivity and sustainability.

Keywords: oyster mushroom, wheat straw, corncobs, cowpea waste.

INTRODUCTION

Due to their direct relationship to human food, edible mushrooms are among the most unique organisms. They are a part of the kingdom Fungi (Mycota), which is estimated to contain 1.5 million species (Niazi and Ghafoor, 2021). This kingdom includes single-cell organisms like yeast as well as complex species that weigh several kilograms and are classified into two main divisions: Ascomycota and Basidiomycota (Cheong, Tan and Fung, 2018). The *Pleurotus* genus, which is the second-largest producer of mushrooms worldwide after *Agaricus bisporus*, contains a wide variety of nutritious fungi with significant commercial value (Bawadekji and Al-Ali, 2016; Alkaisi, 2016). As mentioned by Bouzgarrou (2017), the genus *Pleurotus*, which includes the well-known oyster mushrooms, is part of the Pleurotaceae family. It falls under the Agaricales order, Agaricomycetes class, and Basidiomycota phylum, all within the Fungi kingdom (Mycota). Maslat and Al-Saadawi, (2021) indicated that the general characteristic of the shape of the pilus in the fruiting bodies is convex at the beginning of growth. After that, its

margins curve downward, signifying the fruiting body's maturity. The *Pleurotus* genus comprises over forty species that are grown in tropical and temperate climates across the globe. These species include *P. eryngii*, *P. ostreatus*, *P. djmor*, *P. citrinoplieatus*, *P. tuberregium*, *P. plumonarius*, *P. nebrodensis*, *P. florida*, *P. sabidus*, and *P. cystidiosus* (Bouzgarrou, 2017; Raman *et al*., 2020).The cultivation of Oyster mushroom was first documented experimentally in Germany by Flack in 1917, who started using tree trunks and wood pieces as a basis for his cultivation; then its cultivation became famous in countries around the world (Muswati *et al*., 2021). Furthermore, Raman *et al*. (2021) noted that these species use wet tree trunks and decomposed organic materials as a medium in which they grow because they are rich in lignin. The formation of large quantities of industrial and agricultural waste annually results from increased agricultural activity and the global food industry. Estimates suggest that this waste will reach 126 million tons by 2020 (Ritota and Manzi, 2019). Asia is the largest producer of agricultural waste, primarily from field waste, such as stems, roots, leaves, and crop processing waste like peels and seeds. This continent accounts for 47% of global agricultural waste production, followed by the USA (29%), Europe (16%), Africa (6%), and Oceania (2%) (Kumla *et al*., 2020).

Meng *et al*. (2019) highlighted that China is the top producer of agricultural crop stalk waste, such as corn stalks, bean stalks, and rice straw, which are used to cultivate various edible fungi, including *P. eryngii*, *P. ostreatus*, *P. florida*, and *P. sapidus*. These agricultural residues are ideal for fungal growth due to their lignocellulosic composition, which includes cellulose, hemicellulose, and lignin, as well as smaller amounts of pectin, starch, and other polysaccharides (Gowda and Manvi, 2020; Kumla *et al*., 2020). Fungi have a high capacity to decompose these materials thanks to the enzymes they produce, which are crucial for recycling these substrates in both natural and industrial settings. Common substrates include cotton stalks, sugarcane fibers, rice straw, and wheat straw, which are abundant and widely used in the cultivation of *Pleurotus* spp. (Sekan *et al*., 2019). Iwuagwu *et al*. (2020) also identified other agricultural wastes suitable for growing edible fungi, such as grape waste, sawdust, corncobs, watermelon peels, cowpeas, tree waste, paper waste, sugarcane, sunflower stalks, tea leaves, and palm leaves. The growth of Oyster mushroom (*Pleurotusostreatus*) is influenced by several environmental factors, including nutrition, temperature, ventilation, humidity, light, and pH (Almjalawi *et al*., 2022; Alkaisi *et al*., 2024). First, the mushroom requires nutrients such as carbon, nitrogen, minerals, and vitamins, and it can decompose agricultural waste due to the enzymes it produces (Gowda and Manvi, 2020; Kumla *et al*., 2020). Aditya *et al*. (2024) reported that the optimal temperature for mycelium growth is between 25–30 °C, while the temperature range for fruit body formation is between 10–18 °C. Ventilation is crucial for regulating carbon dioxide and oxygen concentrations, as high carbon dioxide levels can inhibit growth (Zheyang *et al*., 2020). The ideal humidity ranges between 60–75% for mycelial growth and increases to 85–97% during fruit body formation (Bellettini *et al*., 2019). Study conducted by Xie *et al*. (2018) to find the light also plays a role in growth, with blue light helping stimulate fruit body formation. Finally, the optimal pH for the growth substrate ranges from 6–7, with lime added to adjust pH when necessary (Budiono *et al*., 2024). The study aimed to examine these three basic agricultural waste substrates – wheat straw, corncobs with molasses, and cowpea waste – because they are commonly available, cost-effective, and have the potential to support the growth of oyster mushrooms (*Pleurotus* species). By evaluating these substrates, the study sought to identify the most effective and sustainable materials for mushroom cultivation, which could help improve production efficiency and reduce agricultural waste. This approach is beneficial for enhancing both the economic and environmental sustainability of mushroom farming.

MATERIALS AND METHODS

Sources of mushroom species and materials

The mushroom strains (*Pleurotus ostreatus, P. florida*, and *P. sapidus*) obtained from the Iraqi Ministry of Agricultural Plant Protection Directorate, National Centre of Organic Farming. The source is the University of Fujian Agriculture and Forestry, JUNAO Research Institute. Agricultural waste (wheat straw, corncobs, and wheat bran) obtained from local markets.

Effect of substrate and supplementation on mushroom daily growth

The study included the impact three types of agricultural waste on the vertical growth of three oyster mushroom species: *Pleurotus ostreatus, P. florida,* and *P. sapidus.* Agricultural waste were wheat straw (WS), corncobs (CC) as the basic substrate and supplemented with 10% molasses (m) and cowpea waste (c). All treatments supplemented with 25% wheat bran (wb) and 2% $CaCO_3$were applied according to (Al-Saadawi, 2015). The treatments as in the following arrangement:

WS:WS. 73% + wb. 25% + $CaCo_3$ 2% (1)

WS.m: WS. 63% + wb. 25% + + CaCo3 2% + m10% (2)

WS.c: WS. 63% + wb. 25% + + CaCo3 2% + c10% (3)

CC.m: CC. 63% + wb. 25% + + CaCo3 2% + m10% (4)

CC.c: CC. 63% + wb. 25% + + CaCo3 2% + c10% (5)

W.C.m: WS. 31.5%+ CC. 31.5% + + wb. 25% + CaCo3 2% + m10 (6)

W.C.c: WS. 31.5%+ CC. 31.5% + + wb. 25% + CaCo3 2% + c10 (7)

After mixing the treatment prepared by grinding to powder and moistening with water to the appropriate ratio (1:1:25 water: substrates), The substrate was filled into tubes (25 cm); the height of the substrates was 11 cm, with 9 replicates; then the tubes were closed with cotton and sterilized in an autoclave at 121 °C and a pressure of 1.5 kg/cm^2 for 30 minutes. The substrates were inoculated with a 5 mm disc piece from the edge of a modern culture of oyster mushroom species. The incubated at a temperature of 25 °C. After 10 days, readings were taken of the vertical growth of the mycelium separately. The daily growth rate was calculated from Equation 8 (Al-Saadawi, 2015).

$$Daily\ growth\ rate = \frac{The\ distance\ traveled\ by\ the\ mycelium}{The\ number\ of\ days} \quad (8)$$

Effect of substrate and supplementation on productive characteristics

The treatments mentioned above were crushed into small pieces 0.5–1 cm, and they were moistened with water, then packed them in polypropylene bags measuring 20–40 cm. The bags were sterilized in the autoclave at 120 °C for 1 hour. The bags were inoculated with spawn (30 g for one) under sterile conditions inside the laminar device. The bags were incubated at 25–27 °C and a relative humidity of 70% under dark conditions. Once the mycelium had fully colonized the substrate, the temperature was reduced to 15 °C to initiate the fruiting stage. The parameters that have been adopted were the time required for appear pin heads, the total production quantity, and biological calculations using the following equations (Al-Saadawi, 2015; Fufa et al. 2021).

$$Biological\ efficiency\% = \frac{Fresh\ weight\ of\ mushroom(g)}{Dry\ weight\ of\ substrate(g)} \times 100 \quad (9)$$

Statistical analysis

All statistical analysis in this study was carried out using analysis of variance (SAS software version 9.4). All data were calculates from at least 3 replicates and the averages of the coefficients were compared using the least significant difference (LSD) test at the 0.05 probability level.

RESULTS AND DISCUSSION

Evaluation of the effectiveness of substrate in the daily linear growth rate of mycelium of oyster mushroom strains

The results of Table 1 show the efficiency of agricultural waste on the daily linear growth of *Pleurotus* species. The results revealed a significant difference in *P. sapidus* general growth rates, reaching 0.643 cm/day, followed by *P. ostreatus* 0.545 cm/day, and then *P. florida* 0.495 cm/day. The general effect of substrate was in favor CC.c, which recorded 0.693 cm/day compared to the rest of the substrates. The interaction between the substrate and the oyster mushroom species was shown that*, P. sapidus*, *P. ostreatus* and *P. florida* had the highest growth rates on treatment CC.c, recording, 0.796, 0.669 and 0.615 cm/day, respectively, while the lowest daily growth rate for mushrooms was on WS.c treatment, reaching, 0.555, 0.470, and 0.429 cm/day, respectively. Among the substrates for the cultivation of oyster mushroom species, corncob and wheat straw gave the faster mycelial growth rate and daily growth rate. This indicates that there is a relationship

between the substrate and species of oyster mushroom. Corncob substrate is highly promising due to its availability as agricultural waste, its ability to support oyster mushroom growth, and its high water retention capacity (Dhakal *et al*., 2020). Kumla *et al*. (2020) indicated in their study that the substrate of corn cobs is characterized by containing nutritious elements for mushroom growth. This characteristic makes it a good alternative to other substrates. The results were similar to the results of Sitaula *et al*. (2018). On the other hand, wheat straw's also distinguished by physical characteristics and high porosity contribute to its high daily growth rate, even though it dries quickly. This rapid growth rate could be explained by the higher nutrient levels that are available at higher rates, which would provide more energy for mycelial growth and primordial formation.

Effect of substrate and supplemented on completed growth in production bags

The average number of days needed to finish mycelia growth and colonize the entire substrate in bags varied significantly depending on the species of oyster mushrooms. In general, the species *P. florida* was the fastest to invade the entire substrate, with an average of 38.5 days, followed by P. ostreatus 42.9 days, and *P. sapidus* recorded the longest number of days, reaching 50.1 days. The results in Table 2 showed that there were no significant differences between the following three substrates WS.c, WS.m, and CC.m in terms of the number of days required to completely exhaust substrate, as they recoded the lowest number of days, which amounted to 37.8, 39.2, and 39.8 days, respectively. Additionally, the results demonstrated that *P. florida* also excels in the shortest number of days to exhaust all substrate in bags, reaching 33.0 days, followed by *P. ostreatus* and *P. sapidus*, which reach 37.3 and 43.1 days, respectively on W.S.c substrate due to the interaction between oyster mushroom species and the substrates. The longest time to exhaust substrate was observed on CC.c substrate, reaching in *P. florida* 47.9 days*, P. ostreatus* 52.3 days, and *P. florid*a 61.4 days, respectively.

Good growth of mycelium creates suitable conditions for fruiting, and rapid growth and colonization of the substrate is an important economic factor in shortening the period required for production, which achieves a greater number of production cycles and reduces the cost, The difference in the nature of mycelium growth on different agricultural substrate is due to the chemical hydration of the substrate, especially the C\N ratio, as well as the physical properties of the substrate, such as the size of the particles that make up the substrate, where their ideal size ranges between 2–3 cm to allow ventilation and the ability of the medium to retain moisture, taking into account that the medium is It is not compressed in a way that prevents gas exchange and accumulation of metabolites

Table 1. Effect of substrates types on linear growth rate (cm) of oyster mushrooms species

Substrates	Linear growth rate (cm)			Mean	L.S.D. P = 0.05
	P. florida	*P. sapidus*	*P. ostreatus*		
WS.	0.439	0.569	0.481	E 0.499	0.015
CC.m	0.449	0.582	0.491	E 0.507	
WS.c	0.429	0.555	0.470	F 0.482	
CC.c	0.615	0.796	0.669	A 0.693	
W.C.m	0.502	0.650	0.546	C 0.577	
W.C.c	0.477	0.618	0.519	D 0.538	
WS.	0.559	0.724	0.608	B 0.630	
Mean	C 0.495	A 0.643	B 0.545		
L.S.D. of 0.05	0.010				
Mean of interaction of substrates vs mushroom species (SM)					
L.S.D. of 0.05	0.030				

Note: these are the different materials on which the mushrooms are cultivated (WS wheat straw + wheat bran + $CaCo_3$, WS.m wheat straw + wheat bran + $CaCo_3$ + molasses, WS.c wheat straw + wheat bran + $CaCo_3$ + cowpea, CC.m corncobs + wheat bran + $CaCo_3$ + molasses, CC.c corncobs + wheat bran + $CaCo_3$ + cowpea, W.C.m wheat straw+ corncobs + wheat bran + $CaCo_3$ + molasses, W.C.c wheat straw + corncobs + wheat bran + $CaCo_3$ + Cowpea). L.S.D. of 0.05: the least significant difference at a significance level of 0.05, used to compare the statistical differences between the means.

Table 2. Effect of substrates on duration of completion mycelium growth in production bags

Substrates	Colonization period (days)			Mean	L.S.D. P = 0.05
	P. florida	*P. sapidus*	*P. ostreatus*		
WS.m	34.2	44.7	38.6	E 39.2	2.67
CC.m	34.8	45.4	39.2	E D 39.8	
WS.c	33.0	43.1	37.3	E 37.8	
CC.c	47.9	61.4	52.3	A 53.9	
W.C.m	39.6	51.7	43.8	C 45.0	
W.C.c	36.9	48.2	41.6	D 42.2	
WS	43.1	56.2	47.6	B 49.0	
Mean	C 38.5	A 50.1	B 42.9		
L.S.D at 0.05	1.74				
Mean of interaction of substrate vs mushroom species (SM)					
L.S.D. at 0.05	5.08				

Note: treatments: (WS) wheat straw + wheat bran + $CaCo_3$, (WS.m) wheat straw + wheat bran + $CaCo_3$ + molasses, (WS.c) wheat straw + wheat bran + $CaCo_3$ + cowpea, (CC.m) corncobs + wheat bran + $CaCo_3$ + molasses, (CC.c) corncobs + wheat bran + $CaCo_3$ + cowpea, (W.C.m) wheat straw + corncobs + wheat bran + $CaCo_3$ + molasses, (W.C.c) wheat straw + corncobs + wheat bran + $CaCo_3$ + cowpea.

(Rodriguez and Pecchia, 2017). In addition to the genetic difference between laboratory strains, which appeared clear, especially in the *P. florida* isolate, which directly affects the difference in the time required for the completion of mycelia growth over the entire substrate (Girmy *et al,* 2016).

Effect of substrate on time required for pinheads to appear in oyster mushroom strains

The results of Table 3 showed a variation in the number of days required for appearing pinheads on the different substrates. The species *P. florida* was considered the shortest in terms of days, as it recorded a significant difference of 2.60 days. In general, there are no significant differences among WS.c, WS.m, and CC.m treatments, which recorded the lowest number of days required for pinheads at 5.33, 5.44, and 5.56 days, respectively. At the same time, the longest number of days was for the CC.c treatment for all species, which reached 8.67 days.

The interaction between the Oyster mushroom species and the treatment revealed that *P. sapidus* took the longest to appear as a pinhead across all treatments, showing a significant difference from the other two species. While the *P. florida* mushroom achieved the shortest time of 2.0 days on the

Table 3. The effect of substrates and supplementation on period required for the appearance pinheads

Substrates	Period of appearance pinheads (days)			Mean	L.S.D. P = 0.05
	P. florida	*P. sapidus*	*P. ostreatus*		
WS.m	2.33	11.33	2.67	D 5.44	0.829
CC.m	2.00	11.00	3.33	D 5.56	
WS.c	2.00	11.67	2.33	D 5.33	
CC.c	3.33	18.00	4.67	A 8.67	
W.C.m	3.00	12.67	3.50	C 6.50	
W.C.c	2.33	13.17	3.67	C 6.39	
WS.	2.87	12.67	4.67	B 7.40	
Mean	C 2.60	A 13.2	B 3.59		
L.S.D. of 0.05	0.543				
Mean of interaction of substrate vs mushroom species (SM)					
L.S.D. of 0.05	1.41				

Note: treatments: (WS) wheat straw + wheat bran + $CaCo_3$, (WS.m) wheat straw + wheat bran + $CaCo_3$ + molasses, (WS.c) wheat straw + wheat bran + $CaCo_3$ + cowpea, (CC.m) corncobs + wheat bran + $CaCo_3$ + molasses, (CC.c) corncobs + wheat bran + $CaCo_3$ + cowpea, (W.C.m) wheat straw+ corncobs + wheat bran + $CaCo_3$ + molasses, (W.C.c) wheat straw + corncobs + wheat bran + $CaCo_3$ + cowpea.

treatments WS.c and CC.m. The delayed period of pinheads appearance may be due to the substrate containing a high percentage of cellulosic materials and lignin, in which the mushrooms take a longer time to start the stage of forming pinheads compared to the substrates with low levels of cellulosic materials and lignin, and these results are consistent with what was mentioned (Sarita, 2022; El Sebaaly *et al*., 2024).The results of the variation in the duration of the appearance pinheads agreed with Deora *et al.* (2021).

Impact of substrate and supplementation on production of three species of oyster mushrooms

The production of differences based on various treatments were presented in (Table 4).The results showed no significant difference between *P. florida* and *P. sapidus*, with the former achieving the highest rate of total fruiting body weights across all treatments, reaching 197 and 182 gm/bag, respectively. Generally, the W.C.c treatment recorded the highest rate of production, reaching 227 g/bag, while CC.m was the lowest, achieving just 116 g/bag. In addition, the treatments CC.m and WS.c demonstrated the minimum productivity, with an average fruiting body production of 116 and 152 gm/bag, respectively. *P. florida*, *P. ostreatus*, and *P. sapidus* exhibited the highest production yield on treatment W.C.c, recording 256, 226, and 198 gm/bag, respectively. Although *P. ostreatus*, *P. florida* and *P. sapidus* signed the minimum production yield on treatment CC.m., recording 98.0, 110, and 141 gm/bag, respectively. The three oyster mushroom species are characterized by high productivity in wheat bran and corn cobs substrates (Figure 1). Demonstrating the interaction between treatment and oyster mushroom species, the results were similar (Buah *et al*., 2010) who found that *P. ostreatus* outperformed when using corn cobs and wheat bran substrates instead of using sawdust and other treatments. This superiority was attributed to the substrate's high content of nutrients, in addition to the ability of the corn cobs to retain moisture, which constitutes the main support for increasing production (Khorshed and Ahmed, 2023).

Effect of substrates on the biological efficiency of oyster mushroom species

Table 5 shows the variation in biological efficiency according to species of oyster mushrooms studied and quality of the substrate. *P. florida* and *P. sapidus* did not show significant differences in biological efficiency, they recorded 46.7 and 42.6%, respectively. Effect of general rate on substrate shows that the highest biological efficiency was on WS., W.C.c., and WS.m. treatments, reaching 56.7%, 54.8%, and 50.5%, respectively. The CC.m. substrate was the lowest biological efficiency

Table 4. The effect of substrates on the total production quantity of oyster mushroom species *P. florida, P. sapidus* and *P. ostreatus*

Substrates	Mushroom production rate (g)			Mean	L.S.D. P = 0.05
	P. florida	*P. sapidus*	*P. ostreatus*		
WS.m	186	208	134	B 176	35.5
CC.m	110	141	98.0	C 116	
WS.c	178	158	118	C B 152	
CC.c	200	208	123	B 177	
W.C.m	230	176	112	B 173	
W.C.c	256	198	226	A 227	
WS	221	187	149	B 186	
Mean	A 197	A 182	B 137		
L.S.D. of 0.05	23.2				
Mean of interaction of substrates vs mushroom species (SM)					
L.S.D. of 0.05	60.8				

Note: these are the different materials on which the mushrooms are cultivated (WS wheat straw + wheat bran + $CaCo_3$, WS.m wheat straw + wheat bran + $CaCo_3$ + molasses, WS.c wheat straw + wheat bran + $CaCo_3$ + cowpea, CC.m corncobs + wheat bran + $CaCo_3$ + molasses, CC.c corncobs + wheat bran + $CaCo_3$ + cowpea, W.C.m wheat straw+ corncobs + wheat bran + $CaCo_3$ + molasses, W.C.c wheat straw + corncobs + wheat bran + $CaCo_3$ + cowpea). L.S.D. of 0.05: the least significant difference at a significance level of 0.05, used to compare the statistical differences between the means.

Figure 1. Oyster mushroom species represented: (A*) P. ostreatus* (B) *P. florida*, (C) *P. sapidus*

Table 5. The effect of substrates on biological efficiency of oyster mushrooms species *P. florida, P. sapidus* and *P. ostreatus*

Substrates	Mushroom species			Mean	L.S.D. P = 0.05
	P. florida	*P. sapidus*	*P. ostreatus*		
WS.m.	53.4	59.7	38.4	B A 50.5	9.01
CC.m.	14.5	18.6	12.9	D 15.3	
WS.c	51.7	46.0	34.4	B 44.1	
CC.c.	34.1	35.5	20.9	C 30.2	
W.C.m	43.7	33.5	21.2	C 32.8	
W.C.c	61.9	47.8	54.8	A 54.8	
WS.	67.5	57.1	45.4	A 56.7	
Mean	A 46.7	A 42.6	B 32.6		
L.S.D. of 0.05	5.90				
Mean of interaction of substrates vs mushroom species (SM)					
L.S.D of 0.05	15.4				

Note: these are the different materials on which the mushrooms are cultivated (WS wheat straw + wheat bran + CaCo3, WS.m wheat straw + wheat bran + $CaCo_3$ + molasses, WS.c wheat straw + wheat bran + $CaCo_3$ + cowpea, CC.m corncobs + wheat bran + $CaCo_3$ + molasses, CC.c corncobs + wheat bran + $CaCo_3$ + cowpea, W.C.m wheat straw + corncobs + wheat bran + $CaCo_3$ + molasses, W.C.c wheat straw + corncobs + wheat bran + $CaCo_3$ + cowpea). L.S.D. of 0.05: The least significant difference at a significance level of 0.05, used to compare the statistical differences between the means.

reached 15.3%. The interaction between the substrate and the Oyster mushroom species was shown that *P. ostreatus*, *P. florida*, and *P. sapidus* had the lowest biological efficiency on treatment CC.m., recording 12.9%, 14.5%, and 18.6%, respectively, while *P. florida* recorded the highest percentage of biological efficiency on treatment W.C.c. (61.9%) without a significant difference from the control treatment WS., which recorded 67.5%. Biological efficiency is a measure of the substrates ability to produce mushroom fruiting bodies and is one of the most important economic measures in mushroom production (Mkhize *et al*., 2016). Wheat straw is one of the most important substrates used in cultivation of *Pleurotus* spp. on a profitable commercial level by achieving a bio efficiency higher than 50% under conditions for ideal growth, 1 kg of substrate should produce 1 kg of fruiting bodies, and their values vary depending on the number of production units produced from one kilogram of substrate and the ratio of the weight of substrate to the number of production units. This results in a larger space for the fruiting bodies to form and provides nutrients for their development (Ritota and Manzi, 2019). The dry weight of the media used was WS.m. 348 g, CC.m. 755 g, WS.c. 343 g, CC.c. 585 g, W.C.m. 526 g, W.C.c. 413 g, and WS. 327 g. The molecular techniques were used in different filed of biology (Al-Khafaji and Saeed, 2024; Bassi and Al-Rubaii, 2024; Ibrahim and Laftaah, 2024; Abdullah and Al-Rubaii, 2024; Sultan et al, 2023).

CONCLUSIONS

This study provides practical benefits in agriculture and mushroom production by utilizing agricultural waste like wheat straw and corncobs to

improve mushroom yields, making use of locally available resources. It also helps reduce environmental pollution by turning agricultural waste into a valuable product. The use of waste materials promotes more sustainable farming practices, reducing the need for costly fertilizers and chemicals. Additionally, increased mushroom production offers a low-cost, nutritious food source, contributing to food security. By lowering production costs, this approach makes mushroom cultivation more economically viable for farmers. In conclusion, the study promotes sustainable agricultural practices and brings both economic and environmental benefits to food production.

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