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BIOTECHNOLOGICAL EVALUATION OF COFFEE WASTE-BASED COMPOST FOR ENHANCED OYSTER MUSHROOM PRODUCTION AND NUTRITIONAL QUALITY

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Abstract

The effect of coffee waste compost supplementation on growth, yield, biological efficiency and nutritional composition of oyster mushroom (Pleurotus ostreatus) on wheat straw was evaluated. Four different treatments of substrates were prepared: wheat straw as a control (T0), 25% of coffee waste compost and 75% of wheat straw (T1), 50% of coffee waste compost and 50% of wheat straw (T2), and 75% of coffee waste compost and 25% of wheat straw (T3). The results indicated that the mushroom growth and productivity was significantly increased by moderate coffee waste compost. The shortest spawn running time (15.2 ± 0.3 days), earliest pinhead initiation (20.1 ± 0.4 days), highest number of fruiting bodies (38.6 ± 1.2 per bag), maximum fresh yield (1.84 ± 0.03 kg/bag), and highest biological efficiency (92.4%) were recorded in Treatment T2. Treatment T3, however, exhibited mycelial growth delay, yield reduction and impaired biological efficiency, possibly because of high levels of caffeine and phenolics which caused limitation of fungal growth. The nutritional composition was also analyzed and it was determined that mushrooms grown on coffee waste amended substrates possessed higher protein, crude fiber, ash and fat contents with T2 having the highest crude protein content (27.2%). Based on the results, it can be concluded that moderate supplementation of coffee waste compost has positive effect on the use of the substrate, mushroom productivity and nutritional quality,

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but extreme amounts of supplementation have a negative effect on the growth of mushrooms. Hence, it is recommended to use 50% coffee waste compost with wheat straw as an effective and sustainable formulation of substrates for mushroom culture of oyster mushrooms.

Introduction

Industrialization and urbanization have been growing at an alarming rate everywhere leading to the generation of organic wastes in huge quantities. With the global rise in coffee consumption, the most significant agro-industrial by-products that have become problematic in the environment are the coffee wastes (Nath et al., 2023). Every year, millions of tons of spent coffee grounds are created by the coffee-processing industries, cafés, restaurants, hotels and homes. The majority of this waste ends up in landfills or dumping, causing pollution of the environment, greenhouse gas emissions, foul odors and contamination of soil. Coffee waste disposal can lead to environmental issues and significant loss of organic materials, which can be used for sustainable agricultural and biotechnology applications (Ahmed et al., 2024).

The waste coffee grounds are rich in organic compounds such as cellulose, hemicellulose, lignin, proteins, lipids, minerals and phenolic compounds. Coffee waste is a possible substrate for the growth of microorganisms and fungi because of these nutrients. During recent years, the residues from agro-industrial waste have been used as feedstock for the production of valuable materials by environmentally friendly biotechnological processes (Franca & Oliveira, 2022). The best way to make economically acceptable products from organic wastes while minimizing environmental impact is through composting and mushroom farming. The mushroom production using waste materials as substrates promotes sustainable farming practices and strengthens the concept of a circular bioeconomy, as the nutrients from the waste materials are "recycled" back to the food production system (Viriato et al., 2024).

Edible mushrooms are known for their nutritional, medicinal and economic benefits globally. Oyster mushroom or Pleurotus ostreatus is one of the most popular and commercially significant mushrooms because it can grow on diverse environmental conditions, has a short growth period and can be cultivated on a wide variety of substrates as it is a lignocellulosic mushroom (Lesa et al., 2022). Oyster mushrooms have efficient ligninolytic and cellulolytic enzyme systems which are useful in the degradation of complex organic materials like agricultural residues, wood wastes and industrial by-products. The ability of oyster mushrooms to break down low-value waste materials into valuable edible biomass containing significant amounts of proteins, vitamins, minerals, essential amino acids, dietary fibers and bioactive compounds (Kumla et al., 2020) is remarkable.

The chemical composition of the oyster mushroom makes it a good food especially in the developing countries where malnutrition due to deficiency of protein is a serious problem. Oyster mushrooms are low in fat and cholesterol and are a rich source of protein, potassium, phosphorus, iron, calcium and B-complex vitamins. Furthermore, they have medicinal properties such as antioxidant, antimicrobial, anti-inflammatory, anticancer and immune enhancing activity (Effiong et al., 2024). There is significant demand for oyster mushrooms on the global market owing to its nutritional composition and health benefits. Therefore, it is important to identify low cost and sustainable substrates for mushroom production, which has become an area of agricultural and biotechnological studies (Oke et al., 2025).

The oyster mushroom is traditionally grown on wheat straw, rice straw, sawdust, cotton waste, sugarcane bagasse and corn cobs. But, with the rising demand for agricultural residues in livestock feeding, biofuels production and composting, alternative materials of the substrates has been necessary to be explored (Jarial et al., 2024). Coffee waste is noted as a potential source of nutrients and organic matter for substrates. A number of experiments have shown that used coffee grounds, when applied in suitable concentrations, can

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increase the fertility of the substrate and increase mushroom productivity. Coffee waste contains nitrogenous compounds and minerals that can promote mushroom fruiting body nutritional value and stimulate fungus metabolism (Carrasco-Cabrera et al., 2019).

Although this has its benefits, some limitations exist when dealing with direct application of coffee waste in mushroom production. Coffee waste can have high levels of caffeine, tannins and phenolics which might interfere with the growth of fungi and mycelial colonization. Moreover, too much wetness and acidity of coffee waste can have an adverse impact on the aeration of the substrate and microbial balance. Thus it can be said that using the coffee waste for mushroom cultivation is better if the waste is first composted, which would help to reduce organic compounds, toxic material, and enhance the quality of the substrate. Composting improves microbial decomposition and transforms raw coffee waste into an organic compost that is rich in nutrients and can be used to grow fungi (Fayssal et al., 2021).

Coffee waste composting is a beneficial practice for mushroom production in many aspects. It minimises the amount of agro-industrial waste in landfills, decreases environmental pollution, cuts down the costs of waste management and promotes sustainable recycling. Moreover, mushroom production from waste substrates creates value added food products and creates further income opportunities to farmers, small entrepreneurs and rural communities. The process of transforming organic wastes into high-quality edible mushrooms also contributes to food security and sustainable resource management (Singh et al., 2021).

Earlier studies have reported the cultivation success of mushrooms using coffee waste as a substrate but little information is available on the optimum percentage of coffee waste compost needed to optimise the yield and nutritional value of oyster mushroom. Fungal growth can be affected positively or negatively by excessive supplementation and nutrition benefits may not be significant with insufficient supplementation. It is therefore crucial to identify the optimum level of coffee waste compost which will improve mushroom production without exhibiting an inhibitory effect (Ordóñez-García et al., 2025).

The aim of the present study was to assess the biotechnological potential of coffee waste based compost as an alternate substrate supplement for growing mushroom oyster. This study was designed to examine the growth of mycelia and pinhead formation, mushroom yield, biological efficiency and nutritional composition of *Pleurotus ostreatus* on different levels of composting coffee wastes. Results of this study will be valuable for sustainable waste management, environmentally friendly biotechnology, and the preparation of low-cost substitute to mushroom growing media in commercial mushroom cultivation.

Materials and Methods

Experimental Site

The present study was carried under controlled condition of the Biotechnology and Microbiology Laboratory which is suitable for the cultivation of Oyster mushroom. The experimental work was conducted in winter so as to provide optimum temperatures and humidity for the growth of fungi. The incubation temperature was controlled at 22–26 °C in the incubation room and all the relative humidity was controlled at 80–90% during the cultivation. To minimise contamination in the mushroom production, proper ventilation and hygienic conditions were ensured.

Collection of Raw Materials

The spent coffee grounds used in this study were picked up from the local coffee shops, cafés and restaurants. Coffee waste was brought to the laboratory in sterile polyethylene bags, avoiding the possibility of microbial contamination. Oyster mushroom cultivation was conducted using local agricultural farms wheat straw as the main substrate material. The spawn of oyster mushroom (Pleurotus ostreatus) was sourced from a mushroom research and production centre that is certified.

Preparation of Coffee Waste Compost

The gathered coffee waste was shade dried for 48 hours to reduce the hydration level. After drying,

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the coffee grounds were aerobically composted for 30 days to break down potentially harmful chemicals like caffeine and phenolics, while stabilizing organic matter. Composting was carried out in plastic containers by turning the compost regularly every five days to ensure adequate aeration and even decomposition. Water was added to the composting materials as needed to keep them at 60% moisture content. The coffee waste was then composted and had to be sieved to have a fine and uniform appearance in order to prepare the substrate.

Preparation of Wheat Straw

To facilitate handling in substrate and mycelial penetration, wheat straw was chopped into small pieces, about 3-5cm long, was used. Chopped straw was soaked in water for 12 hours to sufficiently increase its moisture content. Once soaked, excess water was removed and the substrate was pasteurized using hot water treatment at 70°C for two hours to remove unwanted microorganisms and contaminants from the substrate. The Pasteurized straw was cooled at room temperature before mixing with coffee waste compost (CWC) (Hoseini et al., 2025).

Experimental Design and Substrate Formulation

The experiment was laid out in a completely random design (CRD) having four treatments and three replications. The coffee waste compost and wheat straw were mixed in various ratios to create the coffee waste compost based substrates. Treatment T0 was used as the control and was made up of 100% wheat straw. The other treatment T1 was made up of 25% coffee waste compost and 75% wheat straw. The 50% coffee waste compost and 50% wheat straw were used in Treatment T2, and the 75% coffee waste compost and 25% wheat straw in Treatment T3. In all cases, 5% gypsum was added to the mixtures to enhance the structure of the substrates and to keep the pH in balance. All substrate formulations were moistened to about 65% before bagging. Approximately 2 kg of the wet substrate was placed in heat-resistant polypropylene bags (about 30 x 40 cm) with small holes made to allow for air and gas exchange during incubation.

Spawning Procedure

The prepared substrate bags were inoculated with oyster mushroom spawn at the rate of 5% of the dry weight of the substrate. Aseptic spawning was carried out in the laboratory to prevent contamination. The spawn was evenly distributed in layers throughout the substrate to ensure uniform mycelial colonization. The spawn bags were then securely sealed and identified for treatment and replication.

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Incubation and Fruiting Conditions

The inoculated bags were kept in a dark incubation room at 25°C for growth of mycelium. The bags were checked for contamination and moisture often during incubation. When there was white fungal mycelium covering the entire surface of the substrate, complete mycelial colonization was recorded. Following complete colonization, small holes were punched in the bags to allow emergence of the fruiting bodies. The bags were then moved to the cropping room where the temperature was kept at 20-25°C with a relative humidity of 85-90%. The mushrooms were grown in suitable environmental conditions by providing light ventilation and water spraying at regular intervals (Rabbi et al., 2019).

Data Collection

The following growth and yield measurements were taken throughout the experimental period. The spawn running time was calculated to be the number of days needed for full colonization of substrate by mycelial growth. Pinhead initiation time was recorded as the number of days taken for the appearance of the first mushroom primordia after spawning. Manual counting of the number of fruiting bodies per bag was performed. Fresh mushroom yield was obtained by weighing mushrooms from each treatment with a digital weighing balance. Biological efficiency was expressed as fresh mushroom weight/dry substrate weight x 100.

Nutritional Analysis

The nutritional composition of fresh mushroom samples taken from each treatment were determined by standard analytical methods recommended by AOAC. The moisture content was calculated by drying in an oven at 105°C to constant weight. The crude protein was determined, following the Kjeldahl method. The estimation of crude fibre was done by acid and alkali digestion method and ash content was estimated by incineration in a muffle furnace at 550°C, while the fat content was estimated by soxhlet extraction method.

Statistical Analysis

All experimental data were statistically analyzed using one-way Analysis of Variance (ANOVA) and significant differences among treatments were determined. The Duncan's Multiple Range Test (DMRT) was used for comparing the mean values at 5% level of significance. Appropriate statistical software packages were used for statistical analysis.

Results

Impact f Coffee Waste Compost on Spawning Time

Coffee waste compost had a significant effect on the growth rate of the mycelium of Pleurotus ostreatus. Treatment T2 with 50% coffee waste compost and 50% wheat straw had the shortest spawn running time with the complete mycelial colonization occurring after 15.2 ± 0.3 days. The treatment T1 (25% coffee waste compost) had the same result as it achieved the highest number of days to reach complete colonization (16.4 ± 0.4 days). The control treatment (T0) was not colonized until 18.6 ± 0.5 days. The colonization time of the longest spawning was obtained in Treatment T3, that is 75% coffee waste compost, being 21.7 ± 0.6 days.

The above mentioned delayed mycelial growth in T3 could be due to the presence of too much of caffeine, tannins, and phenols in coffee wastes which may affect the metabolism of the fungi and degradation of coffee waste. The results show that nutrient levels of moderate coffee waste compost are good for fungal growth while higher levels provide poor conditions for mycelial growth.

Effect on Pinhead Initiation

There were considerable differences between treatments in pinhead initiation time. The earliest appearance of pinhead formation was observed in Treatment T2 on 20.1 ± 0.4 days after spawning, and in Treatment T1 on 21.5 ± 0.5 days after spawning. The pinhead formation days for control treatment was 24.3 ± 0.6 days and Treatment T3 exhibited delayed pinheads initiation at 28.2 ± 0.7 days.

The early pinhead growth seen with moderate coffee waste compost could be attributed to better nutrient availability and microbial breakdown of

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the substrate. Reduced production time and improved commercial efficiency of mushroom production systems are accounted for by increased mushroom initiation speed.

Effect of Coffee Waste Compost on Mushroom Yield

Coffee waste compost had a more significant effect on the fresh yield of oyster mushrooms. The highest fresh mushroom production was 1.84 ± 0.03 kg of mushrooms/cultivation bag obtained from the Treatment T2 among all treatments. Treatment T1 also gave a high yield of 1.67 ± 0.05 kg/bag which was significantly higher than the control treatment. The control treatment (T0) gave a yield of 1.32 ± 0.04 kg per bag and the lowest yield was observed in the Treatment T3 with 1.12 ± 0.06 kg/bag.

The higher production of mushrooms in T1 and T2 might be due to the balanced nutrient content and high organic matter of coffee waste compost. Nitrogen, potassium and carbon compounds were probably responsible for enhancing the enzymatic activity of the fungi and the degradation of the substrates, which led to higher amounts of biomass. In T3, however, excessive coffee waste supplementation may have led to unfavourable conditions for the fungi, which led to a lower productivity.

Biological Efficiency

There were significant differences in biological efficiency (BE) between substrate treatments. Treatment T2 had the highest biological efficiency of 92.4% while Treatment T1 had 83.5%. The biological efficiency was 66.0% for control treatment and lowest biological efficiency (56.0%) was recorded in treatment T3. Treatment T2 with moderate addition of coffee waste compost has higher biological efficiency showing that it improves the utilization and conversion efficiency in the production of oyster mushroom. As the concentration of coffee waste increase, biological efficiency decreased, indicating that high amounts of coffee waste supplementation could be detrimental to fungal growth and nutrient uptake.

Number of Fruiting Bodies

The number of fruiting bodies produced per bag was significantly affected by substrate composition. The highest average number of fruiting bodies was in Treatment T2 with 38.6 ± 1.2 mushrooms per bag followed by Treatment T1 with 34.3 ± 1.0 mushrooms per bag. The control treatment gave a mean of 28.5 ± 0.8 mushrooms per bag, whereas Treatment T3 had the minimum number of mushrooms with a mean of 22.1 ± 0.9 mushrooms per bag. This shows that coffee waste compost at moderate levels (T1 and T2) has the potential to enhance the reproductive growth and fruiting body formation of oyster mushrooms.

Table 1: impact of organic wastes on mushroom yield

Treatments	Substrate Composition	Spawn Running Time (Days)	Pinhead Initiation (Days)	Number of Fruiting Bodies	Fresh Yield (kg/bag)	Biological Efficiency (%)
T0	100% Wheat Straw (Control)	18.6 ± 0.5	24.3 ± 0.6	28.5 ± 0.8	1.32 ± 0.04	66.0
T1	25% Coffee Waste Compost + 75% Wheat Straw	16.4 ± 0.4	21.5 ± 0.5	34.3 ± 1.0	1.67 ± 0.05	83.5
T2	50% Coffee Waste Compost + 50% Wheat Straw	15.2 ± 0.3	20.1 ± 0.4	38.6 ± 1.2	1.84 ± 0.03	92.4
T3	75% Coffee Waste Compost + 25% Wheat Straw	21.7 ± 0.6	28.2 ± 0.7	22.1 ± 0.9	1.12 ± 0.06	56.0

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Nutritional Composition of Oyster Mushrooms

The nutritional analysis results showed that oyster mushrooms' nutritional quality was enhanced by the addition of coffee waste compost as supplemental substrate. The highest crude protein (CP) was found in Treatment T2 (27.2%), followed by Treatment T1 (24.8%) and the control treatment (21.4%). Treatment T3 was slightly lower of protein content than T2 due to low fungal growth efficiency. In the same way, the contents of crude fiber and ash rose in mushrooms grown on substrates containing coffee waste. The highest ash content (7.8%) and crude fibre content (10.6%) were found in the treatment T2. Also, fat content increased slightly with the treatments containing coffee waste compost. The improved nutritional status could be due to the nutrients availability in coffee waste compost; this is loaded with essential minerals and organic compounds that sustain the metabolism of the fungus and the accumulation of nutrients. The findings indicate that the moderate level of coffee waste supplementation can not only enhance mushroom productivity, but it can also increase the nutritional and dietary value of oyster mushrooms (Table 2).

Table 2: impact of organic wastes on nutritional values of mushroom

Treatments	Protein (%)	Crude Fiber (%)	Ash Content (%)	Fat Content (%)	Moisture Content (%)
T0	21.4	8.1	6.2	2.4	89.2
T1	24.8	9.4	7.1	2.7	88.7
T2	27.2	10.6	7.8	3.1	88.1
T3	23.1	9.2	7.0	2.8	87.9

Discussion

The present study showed that the use of composted coffee waste as an appropriate alternative substrate supplement for Pleurotus ostreatus under appropriate concentrations. The mycelial growth, initiation of pinheads, mushroom production, biological efficiency, and nutritional components measured in the experimental plots showed a significant improvement with the addition of moderate level of coffee waste compost, when compared with the control treatment made up of wheat straw alone. Coffee Waste Compost (50% CWC and 50% wheat straw) was found to be the best substrate formulation among all treatments for producing oyster mushroom.

The spawn running time was shorter in Treatments T1 and T2 which indicates good condition for fast mycelial colonization as a result of moderate supplementation with coffee waste compost. Coffee waste is a rich source of nitrogen, carbohydrates, minerals and organic compounds, which can improve the metabolic activity and enzyme activity of fungi. The balanced nutrient composition of coffee waste compost may have facilitated the utilization of the substrate and the oyster mushrooms have high lignocellulolytic enzyme systems that can degrade complex organic substrates (Dissasa, 2022). This enhanced colonization could also be due to the composting process, which decreased the inhibitory components of the materials like caffeine and tannins and increased the nutrient availability. Previous research has shown that supplementing agricultural wastes and residues with nitrogen-rich organic wastes led to improved mycelial growth and shortened spawn running times (Dong et al., 2025).

However, the late colonization observed in Treatment T3 showed that over-application of coffee waste compost had a negative impact on the growth of fungi. Coffee derived phenolic compounds, caffeine and the acidity level could inhibit the growth of mycelium due to adverse effect on the enzyme activity of fungi and the pH of the substrate. In addition, too much coffee waste can decrease substrate porosity and aeration by being too compact and holding onto moisture. Oxygen must be able to diffuse for fungal respiration, and less than optimal substrate structure can restrict mycelial growth. The results highlight the significance of keeping the substrate

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composition balanced to prevent substrate inhibition from excess supplementation (Xiong et al., 2022).
The trend for pinhead initiation was similar to spawn running time with moderate coffee waste supplementation leading to earlier primordial formation. The earlier initiation of pinheads in T1 and T2 treatments might be correlated with increased nutrient supplies and increased physiological activity of the fungus. The abundance of readily decomposable organic material, and required minerals, may have triggered metabolic pathways of reproductive development. The commercial advantage lies in the faster the pinheads are initiated, the shorter the cultivation period and the more they are produced. However, in T3 delayed pinning indicated that by overproduction of the coffee waste, physiological stress conditions were not optimal for fruiting body initiation. The positive impact of medium supplementation of coffee wastes was further supported by the maximum yield of mushrooms and biological efficiency obtained from Treatment T2.
This is the reason for the much greater biological efficiency in T2, which means that the substrates are degraded more efficiently and the nutrients are converted into more efficiently. Coffee waste compost seems to have supplied the extra nitrogen and mineral nutrients to support the growth of fungal enzyme and fungi biomass (Jiang et al., 2023). The higher yield might also be due to the balanced carbon to nitrogen ratio that is provided in the T2 substrate formulation; this ratio is thought to be crucial in the growing of mushrooms. Previous studies have also shown that the addition of nutrient rich organic residues on the lignocellulosic substrate can enhance mushroom productivity and biological efficiency (Baptista et al., 2023).
Coffee waste supplementation in Treatment T3 resulted in reduced yield and biological efficiency, indicating that too much waste can have a negative impact on substrate suitability. Caffeine, tannins and phenolic compounds at high levels can have an inhibitory effect on fungal growth and their efficiency to uptake nutrients. In addition, high nitrogen levels can also interfere with the optimal C:N ratio needed for mushroom growth. The results suggest that coffee waste compost can be used to improve the yield of mushrooms, but its optimal concentration should be determined to prevent the negative effect of toxicity and inhibition (Nuralykyzy et al., 2025).
In T1 and T2, there was also a considerable rise in the number of fruiting bodies produced per bag used. Balanced substrate supplementation can be correlated with increased fruiting body formation, as well as with increased fungal vigor due to improved nutrient availability. This was reflected by the higher fresh yield and the higher biological efficiency observed in T2 which was due to the greater number of mushrooms produced in this treatment. However, the hypothesis of negative effects due to excess coffee waste on fungal reproductive growth is further supported by the decrease in fruiting bodies observed in T3.
The nutritional analysis indicated that the use of coffee waste compost did not only bring benefits to mushroom productivity but also benefited the nutritional quality of the mushrooms harvested. The higher crude protein produced in Treatments T1 and T2 may have been due to the higher nitrogen content of the coffee waste compost that aids the synthesis of amino acids and proteins during the growth of fungi. The minerals accumulated and structural carbohydrate biosynthesis were also increased in mushrooms grown on supplemented substrate. The findings are of significant nutritional interest as mushrooms are rich in protein that can help meet nutritional needs and promote food security, particularly in developing countries (Ionescu et al., 2025).
The small fat content observed in the coffee waste amended treatments could be linked to the fat present in the spent coffee grounds. The overall fat content was relatively low, however, which still adhered to the desirable low fat nutritional profile of oyster mushrooms. The moisture content ranged from 56.5% to 65.8%, with only slight differences among the treatments, suggesting that substrate supplementation had minimal impact on the moisture content of mushroom fruiting bodies (Dawadi et al., 2022).

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Environmentally, the use of coffee waste compost in mushroom cultivation is an excellent environmental and economical solution. Around the world, a lot of spent ground is produced annually and if not disposed of properly, it can cause environmental damage and greenhouse gas emissions. The use of coffee waste as a useful substrate for mushroom growing is an environmentally friendly waste management solution that is in line with the principles of circular bioeconomy. Such a process has the effect of recycling of organic residues to create valuable food products and the prevention of accumulation of waste in landfill facilities (Ungureanu & Vlăduț, 2026).

The economic benefit of using coffee waste compost could be reducing the reliance on traditional substrates used in agriculture and reducing mushroom growers' production costs. Coffee waste is highly available from coffee processing industries and coffee shops and its use as a substrate supplement may be low cost alternative for the commercial mushroom production. Additionally, combining the waste recycling with food production could provide extra income for farmers, entrepreneurs and small-scale industries (Wobiwo et al., 2018).

The results in general revealed that the composted coffee waste is highly biotechnological for sustainable use as a substrate supplement for cultivation of oyster mushroom. Of the tested formulations, 50% coffee waste compost and 50% wheat straw was found to be the best substrate for optimum mushroom growth, yield, bio efficiency and nutritional quality. It is concluded that optimization of substrates is crucial for mushroom biotechnology and can help to develop environmentally friendly methods for utilizing agro-industrial wastes (Gupte et al., 2023).

Research could be conducted in the longer term to assess the viability of the use of coffee waste on a larger scale in commercial mushroom production. Further studies can also be conducted to evaluate the effect of various composting times, sterilization techniques of the substrate and the various combinations of supplements on mushroom productivity and biochemical composition. Furthermore, the detailed analysis of bioactive compounds and antioxidant properties of mushrooms grown on coffee waste could give additional insight into their functional food potential.

Conclusion

In the present study, it was observed that Com-CW can be effectively used as a sustainable substrate supplement for the cultivation of Pleurotus ostreatus. Coffee waste compost is significantly affected mycelial growth, pinhead initiation, mushroom production, biological efficiency and nutritional composition of oyster mushrooms. Overall, the 50% coffee waste compost and 50% wheat straw (Treatment T2) yielded the best results, such as the quickest spawn running time, the earliest pinhead initiation, the highest number of fruiting bodies, the maximum fresh yield, and the greatest biological efficiency of all the substrate formulations tested. The study also showed that coffee waste compost supplementation in moderate levels improved the nutritional value of oyster mushroom by a higher level of crude protein, crude fibre, ash and fat content than the control treatment. The enhanced improvements can be explained due to the abundance of organic matter, nitrogen and mineral content found in the Composed Coffee Waste which promoted fungal metabolism and substrate biodegradation. But high concentration of coffee waste compost (75%) leads to mushroom growth inhibition and lower productivity probably due to presence of inhibitory amounts of compounds like caffeine, tannins and phenolics and lower aeration of the substrate. The results indicate that coffee waste compost is a promising environmentally friendly and cost-effective alternative substrate supplement for mushroom growing. The use of spent coffee grounds in mushroom cultivation offers a sustainable approach to agriculture and also supports the effective recycling of organic waste, reduction of environmental pollution and the promotion of circular bioeconomy practices. Moreover, this could offer other economic potentials for mushroom producers and small-scale farm-based sectors in utilizing agro-industrial wastes into nutritious and valuable food products. Based on

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the results of this study, the best formulation of the substrate for the production of the oyster mushroom was determined to be a combination of 50% coffee waste compost and 50% wheat straw. The findings of this research project justify the integration of coffee waste recycling for future sustainable mushroom biotechnology and further research into the commercial scale and optimizing waste-based cultivation systems.

References

Ahmed, H., et al. (2024). Toward circular economy: Potentials of spent coffee grounds in bioproducts and chemical production. *Biomass, 4*(2): 286-312.

Baptista, F., et al. (2023). Unlocking the potential of spent mushroom substrate (SMS) for enhanced agricultural sustainability: from environmental benefits to poultry nutrition. *Life, 13*(10): 1948.

Carrasco-Cabrera, C. P., et al. (2019). Caffeine metabolism during cultivation of oyster mushroom (Pleurotus ostreatus) with spent coffee grounds. *Applied microbiology and biotechnology, 103*(14): 5831-5841.

Dawadi, E., et al. (2022). Nutritional and post-harvest quality preservation of mushrooms: A review. *Heliyon, 8*(12).

Dissasa, G. (2022). Cultivation of different oyster mushroom (Pleurotus species) on coffee waste and determination of their relative biological efficiency and pectinase enzyme production, Ethiopia. *International Journal of Microbiology, 2022*(1): 5219939.

Dong, H.-R., et al. (2025). Research Progress and Prospect of Substrate Alternatives for Edible Fungi Based on the "Cycle Production of Plants, Animals, and Fungi". *Journal of Fungi, 11*(11): 790.

Effiong, M. E., et al. (2024). Assessing the nutritional quality of Pleurotus ostreatus (oyster mushroom). *Frontiers in Nutrition, 10*: 1279208.

Fayssal, S. A., et al. (2021). Improvement of compost quality *Mushrooms: Agaricus bisporus* (pp. 136-189): CABI Wallingford UK.

Franca, A. S., & Oliveira, L. S. (2022). Potential uses of spent coffee grounds in the food industry. *Foods, 11*(14): 2064.

Gupte, A., et al. (2023). Agro-industrial residues: an eco-friendly and inexpensive substrate for fungi in the development of white biotechnology *Fungi and fungal products in human welfare and biotechnology* (pp. 571-603): Springer.

Hoseini, M., et al. (2025). Producing agri-food derived composts from coffee husk as primary feedstock at different temperature conditions. *Journal of Environmental Management, 373*: 123485.

Ionescu, M., et al. (2025). Proteins from edible mushrooms: Nutritional role and contribution to well-being. *Foods, 14*(18): 3201.

Jarial, R., et al. (2024). Comprehensive review on oyster mushroom species (Agaricomycetes): Morphology, nutrition, cultivation and future aspects. *Heliyon, 10*(5).

Jiang, Z., et al. (2023). Combined application of coffee husk compost and inorganic fertilizer to improve the soil ecological environment and photosynthetic characteristics of arabica coffee. *Agronomy, 13*(5): 1212.

Kumla, J., et al. (2020). Cultivation of mushrooms and their lignocellulolytic enzyme production through the utilization of agro-industrial waste. *Molecules, 25*(12): 2811.

Lesa, K. N., et al. (2022). Nutritional value, medicinal importance, and health-promoting effects of dietary mushroom (Pleurotus ostreatus). *Journal of Food Quality, 2022*(1): 2454180.

Nath, A., et al. (2023). Global status of agricultural waste-based industries, challenges, and future prospects. *Agricultural Waste to Value-Added Products: Technical, Economic and Sustainable Aspects*: 21-45.

Frontier in Medical & Health Research
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Nuralykyzy, B., et al. (2025). Synergies between Carbon Sequestration, Nitrogen Utilization, and Mushroom Quality: A Comprehensive Review of Substrate, Fungi, and Soil Interactions. *Journal of agricultural and food chemistry, 73*(23): 14144-14157.

Oke, M., et al. (2025). Global Market Prospects and Opportunities for Oyster Mushrooms *Pleurotus* (pp. 195-210): CRC Press.

Ordóñez-García, M., et al. (2025). Agro-industrial Waste Management Practices for Sustainable Development *Agroindustrial Waste Management and Natural Resources Conservation* (pp. 1-23): Apple Academic Press.

Rabbi, B., et al. (2019). Protected cropping in warm climates: A review of humidity control and cooling methods. *Energies, 12*(14): 2737.

Singh, R., et al. (2021). Utilisation of agro-industrial waste for sustainable green production: a review. *Environmental Sustainability, 4*(4): 619-636.

Ungureanu, N., & Vlăduţ, N.-V. (2026). Sustainable Valorization of Spent Coffee Grounds Within the Circular Economy: Innovative Applications in Food, Agriculture, Environmental, and Industrial Sectors. *Sustainability, 18*(8): 4127.

Viriato, V., et al. (2024). A business model for circular bioeconomy: edible mushroom production and its alignment with the sustainable development goals (SDGs). *Recycling, 9*(4): 68.

Wobiwo, F. A., et al. (2018). Valorization of spent coffee ground with wheat or miscanthus straw: Yield improvement by the combined conversion to mushrooms and biomethane. *Energy for Sustainable Development, 45*: 171-179.

Xiong, B.-J., et al. (2022). Impact of fungal hyphae on growth and dispersal of obligate anaerobic bacteria in aerated habitats. *Mbio, 13*(3): e00769-00722.