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

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Abstract

This study evaluated the effect of coffee waste compost supplementation on the growth, yield, biological efficiency, and nutritional composition of oyster mushroom (Pleurotus ostreatus) cultivated on wheat straw substrate. Four substrate treatments were prepared: T0 (100% wheat straw as control), T1 (25% coffee waste compost + 75% wheat straw), T2 (50% coffee waste compost + 50% wheat straw), and T3 (75% coffee waste compost + 25% wheat straw). Results showed that moderate incorporation of coffee waste compost significantly improved mushroom growth and productivity. 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. In contrast, Treatment T3 showed delayed mycelial growth, reduced yield, and lower biological efficiency, likely due to excessive concentrations of caffeine and phenolic compounds that inhibited fungal development. Nutritional analysis further revealed that mushrooms cultivated on coffee waste-amended substrates had improved protein, crude fiber, ash, and fat contents, with T2 showing the

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highest crude protein content (27.2%). The findings indicate that moderate supplementation of coffee waste compost enhances substrate utilization, mushroom productivity, and nutritional quality, while excessive supplementation negatively affects fungal growth. Therefore, the use of 50% coffee waste compost with wheat straw is recommended as an effective and sustainable substrate formulation for oyster mushroom cultivation.

INTRODUCTION

The rapid growth of industrialization and urbanization has led to a significant increase in the generation of organic waste materials across the world. Among various agro-industrial residues, coffee waste has emerged as one of the most abundant and environmentally challenging by-products due to the increasing global consumption of coffee (Nath et al., 2023). Millions of tons of spent coffee grounds are generated annually from coffee-processing industries, cafés, restaurants, hotels, and households. Most of this waste is disposed of in landfills or open dumping sites, which contributes to environmental pollution, greenhouse gas emissions, unpleasant odors, and soil contamination. The improper disposal of coffee waste not only creates ecological concerns but also results in the loss of valuable organic resources that could otherwise be utilized for sustainable agricultural and biotechnological applications (Ahmed et al., 2024; Afzal et al., 2025).

Spent coffee grounds contain substantial amounts of organic matter, including cellulose, hemicellulose, lignin, proteins, lipids, minerals, and phenolic compounds. These nutrients make coffee waste a potentially valuable substrate for microbial and fungal growth. In recent years, researchers have focused on transforming agro-industrial residues into useful products through environmentally friendly biotechnological approaches (Franca & Oliveira, 2022). Composting and mushroom cultivation are among the most effective methods for converting organic waste into economically valuable products while minimizing environmental impacts. The use of waste materials in mushroom production supports sustainable agriculture and contributes to the development of a circular bioeconomy by recycling nutrients back into the food production system (Viriato et al., 2024).

Edible mushrooms are recognized worldwide for their nutritional, medicinal, and economic importance. Among cultivated mushroom species, oyster mushroom (*Pleurotus ostreatus*) is one of the most popular and commercially important fungi due to its simple cultivation techniques, rapid growth rate, adaptability to diverse environmental conditions, and ability to grow on a wide variety of lignocellulosic substrates (Lesa et al., 2022). Oyster mushrooms possess efficient ligninolytic and cellulolytic enzyme systems that enable them to degrade complex organic materials such as agricultural residues, wood wastes, and industrial by-products. This remarkable biodegradation capability allows oyster mushrooms to convert low-value waste materials into high-quality edible biomass rich in proteins, vitamins, minerals, essential amino acids, dietary fibers, and bioactive compounds (Kumla et al., 2020).

The nutritional composition of oyster mushrooms makes them an excellent source of food, particularly in developing countries where protein malnutrition remains a serious concern. Oyster mushrooms contain low fat and cholesterol levels while providing significant amounts of protein, potassium, phosphorus, iron, calcium, and B-complex vitamins. Additionally, they possess medicinal properties including antioxidant, antimicrobial, anti-inflammatory, anticancer, and immune-enhancing activities (Effiong et al., 2024). Due to their high nutritional value and health benefits, the demand for oyster mushrooms has increased considerably in global markets. Consequently, identifying low-cost and sustainable substrates for mushroom cultivation has become an important area of agricultural and biotechnological research (Oke et al., 2025).

Traditionally, oyster mushrooms are cultivated on substrates such as wheat straw, rice straw, sawdust, cotton waste, sugarcane bagasse, and corn cobs.

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However, increasing demand for agricultural residues in livestock feeding, biofuel production, and composting has created the need to explore alternative substrate materials (Jarial et al., 2024). Coffee waste has attracted attention as a promising substrate supplement because of its high organic matter and nutrient content. Several studies have demonstrated that spent coffee grounds can improve substrate fertility and enhance mushroom productivity when used in appropriate concentrations. The presence of nitrogenous compounds and minerals in coffee waste can stimulate fungal metabolism and improve the nutritional quality of mushroom fruiting bodies (Carrasco-Cabrera et al., 2019).

Despite its advantages, the direct use of coffee waste in mushroom cultivation presents certain limitations. Fresh coffee waste may contain high concentrations of caffeine, tannins, and phenolic compounds that can inhibit fungal growth and mycelial colonization. In addition, excessive moisture retention and acidity of coffee waste may negatively affect substrate aeration and microbial balance. Therefore, composting coffee waste before utilization is considered an effective strategy to stabilize organic matter, reduce toxic compounds, and improve substrate quality for mushroom cultivation. Composting enhances microbial decomposition and converts raw coffee residues into nutrient-rich organic compost suitable for fungal growth (Fayssal et al., 2021).

The integration of coffee waste compost into mushroom cultivation systems offers several environmental and economic benefits. It reduces the accumulation of agro-industrial waste in landfills, lowers environmental pollution, decreases waste management costs, and promotes sustainable recycling practices. Furthermore, mushroom cultivation using waste substrates generates value-added food products and provides additional income opportunities for farmers, small-scale entrepreneurs, and rural communities. The conversion of organic waste into nutritious edible mushrooms also supports food security and sustainable resource management (Singh et al., 2021).

Although previous studies have reported the successful use of coffee waste in mushroom cultivation, limited information is available regarding the optimal proportion of coffee waste compost required to maximize oyster mushroom yield and nutritional quality. Excessive supplementation may negatively influence fungal growth, while insufficient supplementation may not provide significant nutritional benefits. Therefore, it is important to determine the appropriate concentration of coffee waste compost that can enhance mushroom production without causing inhibitory effects (Ordóñez-García et al., 2025).

The present study was conducted to evaluate the biotechnological potential of coffee waste-based compost as an alternative substrate supplement for oyster mushroom cultivation. The study aimed to investigate the effects of different levels of coffee waste compost on mycelial growth, pinhead formation, mushroom yield, biological efficiency, and nutritional composition of *Pleurotus ostreatus*. The findings of this research are expected to contribute to sustainable waste management practices, environmentally friendly biotechnology, and the development of low-cost substrate alternatives for commercial mushroom production.

Materials and Methods

Experimental Site

The present study was conducted in the Biotechnology and Microbiology Laboratory under controlled environmental conditions suitable for oyster mushroom cultivation. The experimental work was carried out during the winter season to maintain favorable temperature and humidity conditions for fungal growth. The incubation room temperature was maintained between 22°C and 26°C, while the relative humidity was controlled at 80–90% throughout the cultivation period. Proper ventilation and hygienic conditions were ensured to minimize contamination during mushroom production.

Collection of Raw Materials

Spent coffee grounds used in this study were collected from local coffee shops, cafés, and restaurants. Fresh coffee waste was transported to the laboratory in sterile polyethylene bags to avoid

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microbial contamination. Wheat straw was obtained from local agricultural farms and used as the primary substrate material for oyster mushroom cultivation. Oyster mushroom (*Pleurotus ostreatus*) spawn was procured from a certified mushroom research and production center.

Preparation of Coffee Waste Compost

The collected coffee waste was first air-dried under shade conditions for 48 hours to reduce excess moisture content. The dried coffee grounds were then subjected to aerobic composting for 30 days to stabilize organic matter and reduce toxic compounds such as caffeine and phenolics. Composting was performed in plastic containers with regular turning every five days to ensure proper aeration and uniform decomposition. Moisture content during composting was maintained at approximately 60% by sprinkling water when necessary. After compost maturation, the composted coffee waste was sieved to obtain a fine and uniform texture suitable for substrate preparation.

Preparation of Wheat Straw

Wheat straw was chopped into small pieces approximately 3–5 cm in length to improve substrate handling and mycelial penetration. The chopped straw was soaked in water for 12 hours to achieve adequate moisture content. After soaking, excess water was drained, and the substrate was pasteurized by hot water treatment at 70°C for two hours to eliminate unwanted microorganisms and contaminants. The pasteurized straw was cooled at room temperature before mixing with coffee waste compost (Hoseini et al., 2025).

Experimental Design and Substrate Formulation

The experiment was arranged in a completely randomized design (CRD) with four treatments and three replications. Different proportions of coffee waste compost and wheat straw were used to prepare the substrate formulations. Treatment T0 served as the control and consisted of 100% wheat straw. Treatment T1 contained 25% coffee waste compost and 75% wheat straw. Treatment T2 consisted of 50% coffee waste compost and 50% wheat straw, while Treatment T3 contained 75% coffee waste compost and 25% wheat straw. All substrate mixtures were supplemented with 5% gypsum to improve substrate structure and maintain pH balance. The moisture content of all substrate formulations was adjusted to approximately 65% before bag filling. About 2 kg of wet substrate was packed into heat-resistant polypropylene bags measuring approximately 30 × 40 cm. Small holes were made in the bags to facilitate aeration and gas exchange during incubation.

Spawning Procedure

Oyster mushroom spawn was inoculated into the prepared substrate bags at a spawning rate of 5% of the dry substrate weight. Spawning was performed aseptically under sterilized laboratory conditions to avoid contamination. The spawn was evenly distributed in layers throughout the substrate to ensure uniform mycelial colonization. After spawning, the bags were tightly closed and labeled according to treatment type and replication number.

Incubation and Fruiting Conditions

The inoculated bags were transferred to a dark incubation room maintained at 25°C for mycelial growth. During incubation, the bags were regularly monitored for contamination and moisture status. Complete mycelial colonization of the substrate was recorded when the entire substrate surface became covered with white fungal mycelium. After full colonization, small openings were made in the bags to facilitate fruiting body emergence. The bags were then transferred to the cropping room where temperature was maintained between 20°C and 25°C with relative humidity of 85–90%. Light ventilation and periodic water spraying were provided to maintain suitable environmental conditions for mushroom development (Rabbi et al., 2019).

Data Collection

Various growth and yield parameters were recorded during the experimental period. Spawn running time was measured as the number of days required for complete mycelial colonization of the

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substrate. Pinhead initiation time was recorded as the number of days taken for the appearance of the first mushroom primordia after spawning. The number of fruiting bodies produced in each bag was counted manually. Fresh mushroom yield was determined by weighing harvested mushrooms from each treatment using a digital weighing balance. Biological efficiency was calculated as the ratio of fresh mushroom weight to dry substrate weight multiplied by 100.

Nutritional Analysis

Fresh mushroom samples collected from each treatment were analyzed for nutritional composition using standard analytical procedures recommended by the Association of Official Analytical Chemists (AOAC). Moisture content was determined by oven drying at 105°C until constant weight was achieved. Crude protein content was analyzed using the Kjeldahl method. Crude fiber was estimated by acid and alkali digestion methods, while ash content was determined through incineration in a muffle furnace at 550°C. Fat content was measured using Soxhlet extraction techniques.

Statistical Analysis

All experimental data were statistically analyzed using one-way analysis of variance (ANOVA) to determine significant differences among treatments. Mean values were compared using Duncan's Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$. The statistical analysis was performed using appropriate statistical software packages.

Results

Effect of Coffee Waste Compost on Spawn Running Time

The incorporation of coffee waste compost significantly influenced the mycelial growth rate of *Pleurotus ostreatus*. The shortest spawn running time was observed in Treatment T2 containing 50% coffee waste compost and 50% wheat straw, where complete mycelial colonization occurred within 15.2 ± 0.3 days. Treatment T1 (25% coffee waste compost) also showed rapid mycelial growth with complete colonization achieved in 16.4 ± 0.4 days. In contrast, the control treatment (T0) required 18.6 ± 0.5 days for full substrate colonization. The longest spawn running time was recorded in Treatment T3 containing 75% coffee waste compost, where colonization required 21.7 ± 0.6 days.

The delayed mycelial growth observed in T3 may be attributed to the excessive concentration of caffeine, tannins, and phenolic compounds present in coffee waste, which may inhibit fungal metabolism and substrate degradation. The results indicate that moderate levels of coffee waste compost create favorable nutritional conditions for fungal growth, whereas excessive supplementation negatively affects mycelial development.

Effect on Pinhead Initiation

Significant variations were observed among treatments regarding pinhead initiation time. The earliest pinhead formation was recorded in Treatment T2 at 20.1 ± 0.4 days after spawning, followed by Treatment T1 at 21.5 ± 0.5 days. The control treatment required 24.3 ± 0.6 days for pinhead formation, while Treatment T3 showed delayed initiation at 28.2 ± 0.7 days.

The earlier pinhead formation observed in treatments containing moderate coffee waste compost may be due to improved nutrient availability and enhanced microbial decomposition of the substrate. Faster pinhead initiation contributes to shorter production cycles and increased commercial efficiency in mushroom cultivation.

Effect of Coffee Waste Compost on Mushroom Yield

The addition of coffee waste compost significantly enhanced the fresh yield of oyster mushrooms. Among all treatments, Treatment T2 produced the highest fresh mushroom yield of 1.84 ± 0.03 kg per cultivation bag. Treatment T1 also produced a high yield of 1.67 ± 0.05 kg per bag, which was significantly greater than the control treatment. The control treatment (T0) yielded 1.32 ± 0.04 kg per bag, while Treatment T3 produced the lowest yield of 1.12 ± 0.06 kg per bag.

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The increase in mushroom yield observed in Treatments T1 and T2 may be associated with the balanced nutrient composition and high organic matter content of coffee waste compost. The presence of nitrogen, potassium, and carbon compounds likely stimulated fungal enzymatic activity and substrate biodegradation, resulting in improved biomass production. However, excessive coffee waste supplementation in T3 may have created unfavorable substrate conditions that reduced fungal productivity.

Biological Efficiency

Biological efficiency (BE) differed significantly among the substrate treatments. Treatment T2 recorded the highest biological efficiency of 92.4%, followed by Treatment T1 with 83.5%. The control treatment showed a biological efficiency of 66.0%, whereas the lowest value of 56.0% was observed in Treatment T3. The superior biological efficiency of Treatment T2 demonstrates that moderate incorporation of coffee waste compost enhances substrate utilization and conversion efficiency in oyster mushroom cultivation. The decline in biological efficiency at higher coffee waste concentrations suggests that excessive supplementation may interfere with fungal growth and nutrient absorption.

Number of Fruiting Bodies

The number of fruiting bodies produced per bag was significantly affected by substrate composition. Treatment T2 produced the highest average number of fruiting bodies with 38.6 ± 1.2 mushrooms per bag, followed by Treatment T1 with 34.3 ± 1.0 mushrooms. The control treatment produced 28.5 ± 0.8 mushrooms per bag, while Treatment T3 recorded the lowest number of fruiting bodies at 22.1 ± 0.9 mushrooms. The increased number of fruiting bodies in Treatments T1 and T2 indicates that coffee waste compost at moderate levels promotes better reproductive growth and fruiting body formation in 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

Nutritional Composition of Oyster Mushrooms

The nutritional analysis revealed that substrate supplementation with coffee waste compost significantly improved the nutritional quality of oyster mushrooms. The highest crude protein content was observed in Treatment T2 (27.2%), followed by Treatment T1 (24.8%), whereas the control treatment contained 21.4% protein. Treatment T3 showed a slightly lower protein content compared to T2 due to reduced fungal growth efficiency. Similarly, crude fiber and ash contents increased in mushrooms cultivated on coffee waste-amended substrates. Treatment T2 exhibited the highest crude fiber content (10.6%)

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and ash content (7.8%). Fat content also showed a slight increase in treatments containing coffee waste compost. The enhancement in nutritional composition may be attributed to the nutrient-rich nature of coffee waste compost, which contains essential minerals and organic compounds that support fungal metabolism and nutrient accumulation. The results suggest that moderate coffee waste supplementation not only improves mushroom productivity but also enhances 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 demonstrated that composted coffee waste can serve as an effective alternative substrate supplement for the cultivation of *Pleurotus ostreatus* when applied at appropriate concentrations. The results clearly indicated that the incorporation of moderate levels of coffee waste compost significantly improved mycelial growth, pinhead initiation, mushroom yield, biological efficiency, and nutritional composition compared to the control treatment consisting solely of wheat straw. Among all treatments, Treatment T2 containing 50% coffee waste compost and 50% wheat straw proved to be the most effective substrate formulation for oyster mushroom production.

The shorter spawn running time observed in Treatments T1 and T2 suggests that moderate supplementation with coffee waste compost created favorable conditions for rapid mycelial colonization. Coffee waste contains substantial amounts of nitrogen, carbohydrates, minerals, and organic compounds that may enhance fungal metabolism and enzymatic activity. Oyster mushrooms possess strong lignocellulolytic enzyme systems capable of degrading complex organic substrates, and the balanced nutrient composition of coffee waste compost likely promoted efficient substrate utilization (Dissasa, 2022). The accelerated colonization observed in T2 may also be attributed to the composting process, which reduced inhibitory compounds such as caffeine and tannins while improving nutrient availability. Similar findings have been reported in previous studies where supplementation of agricultural residues with nitrogen-rich organic wastes enhanced mycelial growth and reduced spawn running periods (Dong et al., 2025).

In contrast, the delayed colonization recorded in Treatment T3 indicated that excessive incorporation of coffee waste compost negatively affected fungal growth. High concentrations of coffee-derived phenolic compounds, caffeine, and acidic components may inhibit mycelial development by interfering with fungal enzymatic processes and altering substrate pH. Furthermore, excessive coffee waste may reduce substrate porosity and aeration due to its compact texture and high moisture retention capacity. Adequate aeration is essential for oxygen diffusion during fungal respiration, and poor substrate structure may limit mycelial expansion. These findings emphasize the importance of maintaining a balanced substrate composition to avoid inhibitory effects associated with excessive supplementation (Xiong et al., 2022).

Pinhead initiation followed a trend similar to spawn running time, where moderate coffee waste supplementation promoted earlier primordial formation. Earlier pinhead initiation in Treatments T1 and T2 may be associated with improved nutrient availability and enhanced physiological activity of the fungus. The availability of readily degradable organic matter and essential minerals likely stimulated metabolic

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pathways involved in reproductive development. Faster pinhead initiation is commercially advantageous because it shortens the cultivation cycle and increases production efficiency. However, delayed pinning in T3 suggests that excessive coffee waste created physiological stress conditions unfavorable for fruiting body initiation. The highest mushroom yield and biological efficiency recorded in Treatment T2 further confirmed the beneficial effects of moderate coffee waste supplementation.

The significantly higher biological efficiency observed in T2 indicates improved substrate degradation and nutrient conversion efficiency. Coffee waste compost likely provided additional nitrogen and mineral nutrients that enhanced fungal enzyme production and biomass accumulation (Jiang et al., 2023). The increased yield may also be related to the balanced carbon-to-nitrogen ratio achieved in the T2 substrate formulation, which is considered essential for optimal mushroom cultivation. Previous research has similarly demonstrated that supplementation of lignocellulosic substrates with nutrient-rich organic residues can improve mushroom productivity and biological efficiency (Baptista et al., 2023).

The reduction in yield and biological efficiency observed in Treatment T3 suggests that excessive coffee waste supplementation can negatively affect substrate suitability. High levels of caffeine, tannins, and phenolic compounds may inhibit fungal growth and reduce nutrient uptake efficiency. Additionally, excessive nitrogen levels may disrupt the optimal carbon-to-nitrogen balance required for mushroom development. These findings indicate that while coffee waste compost can enhance mushroom production, its concentration must be carefully optimized to avoid toxic or inhibitory effects (Nuralykyzy et al., 2025).

The number of fruiting bodies produced per cultivation bag also increased significantly in Treatments T1 and T2. Increased fruiting body formation may be associated with improved nutrient availability and enhanced fungal vigor resulting from balanced substrate supplementation. The greater number of mushrooms produced in T2 contributed directly to the higher fresh yield and biological efficiency observed in this treatment. Conversely, the reduced number of fruiting bodies in T3 further supports the hypothesis that excessive coffee waste negatively affects fungal reproductive growth.

The nutritional analysis revealed that coffee waste compost not only improved mushroom productivity but also enhanced the nutritional quality of the harvested mushrooms. The increased crude protein content observed in Treatments T1 and T2 may be attributed to the higher nitrogen content of coffee waste compost, which supports amino acid and protein synthesis during fungal growth. Mushrooms cultivated on supplemented substrates also exhibited higher crude fiber and ash contents, indicating improved mineral accumulation and structural carbohydrate synthesis. These findings are particularly important from a nutritional perspective because protein-rich mushrooms can contribute to dietary improvement and food security, especially in developing countries (Ionescu et al., 2025).

The slight increase in fat content observed in coffee waste-amended treatments may be associated with the lipid content naturally present in spent coffee grounds. However, the fat levels remained relatively low overall, preserving the desirable low-fat nutritional profile of oyster mushrooms. Moisture content showed only minor variations among treatments, indicating that substrate supplementation had limited influence on the water composition of mushroom fruiting bodies (Dawadi et al., 2022).

From an environmental perspective, the utilization of coffee waste compost for mushroom cultivation offers significant ecological and economic advantages. Large quantities of spent coffee grounds are generated globally each year, and improper disposal contributes to environmental pollution and greenhouse gas emissions. The conversion of coffee waste into a productive substrate for mushroom cultivation represents an environmentally sustainable waste management strategy that supports circular bioeconomy principles. This approach promotes recycling of organic residues into valuable food

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products while reducing waste accumulation in landfills (Ungureanu & Vlăduţ, 2026).

Economically, the use of coffee waste compost may reduce dependence on conventional agricultural substrates and lower production costs for mushroom growers. Since coffee waste is abundantly available from cafés, restaurants, and coffee-processing industries, its utilization as a substrate supplement could provide a low-cost alternative for commercial mushroom cultivation. Furthermore, integrating waste recycling with food production may create additional income opportunities for farmers, entrepreneurs, and small-scale industries (Wobiwo et al., 2018).

Overall, the findings of the present study demonstrate that composted coffee waste has strong biotechnological potential as a sustainable substrate supplement for oyster mushroom cultivation. Among the tested formulations, the combination of 50% coffee waste compost and 50% wheat straw was identified as the most suitable substrate for maximizing mushroom growth, yield, biological efficiency, and nutritional quality. The study highlights the importance of substrate optimization in mushroom biotechnology and supports the development of environmentally friendly approaches for agro-industrial waste utilization (Gupte et al., 2023).

Future studies may focus on evaluating the long-term economic feasibility of large-scale coffee waste utilization in commercial mushroom production. Additional research may also investigate the effects of different composting durations, substrate sterilization methods, and supplementation combinations on mushroom productivity and biochemical composition. Moreover, detailed analysis of bioactive compounds and antioxidant properties of mushrooms cultivated on coffee waste substrates may provide further insights into their functional food potential.

Conclusion

The present study demonstrated that composted coffee waste can be effectively utilized as a sustainable substrate supplement for the cultivation of Pleurotus ostreatus. The incorporation of coffee waste compost significantly influenced mycelial growth, pinhead initiation, mushroom yield, biological efficiency, and nutritional composition of oyster mushrooms. Among all substrate formulations, Treatment T2 containing 50% coffee waste compost and 50% wheat straw produced the best overall results, including the shortest spawn running time, earliest pinhead initiation, highest number of fruiting bodies, maximum fresh yield, and greatest biological efficiency. The study further revealed that moderate supplementation with coffee waste compost enhanced the nutritional quality of oyster mushrooms by increasing crude protein, crude fiber, ash, and fat contents compared to the control treatment. These improvements may be attributed to the rich organic matter, nitrogen, and mineral content present in composted coffee waste, which supported fungal metabolism and substrate biodegradation. However, excessive incorporation of coffee waste compost (75%) negatively affected mushroom growth and productivity, likely due to the presence of inhibitory compounds such as caffeine, tannins, and phenolic substances, as well as reduced substrate aeration. The findings highlight the potential of coffee waste compost as an environmentally friendly and low-cost alternative substrate supplement for mushroom cultivation. Utilization of spent coffee grounds in mushroom production not only improves agricultural sustainability but also contributes to effective organic waste recycling, reduction of environmental pollution, and development of circular bioeconomy practices. Furthermore, this approach may provide additional economic opportunities for mushroom growers and small-scale agricultural industries through the conversion of agro-industrial waste into valuable nutritious food products. In conclusion, the combination of 50% coffee waste compost and 50% wheat straw was identified as the optimal substrate formulation for oyster mushroom cultivation under the conditions of the present study. The research supports the integration of coffee waste recycling into sustainable mushroom biotechnology and encourages further investigations into large-scale commercial

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applications and optimization of waste-based cultivation systems.

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