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INNOVATIVE FUNGAL STRATEGIES FOR SUSTAINABLE FOREST MANAGEMENT: THE ROLE OF *PLEUROTUS CITRINOPILEATUS* IN WILDFIRE RISK MITIGATION

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Abstract

Rising frequency and intensity of forest fires seriously affect biodiversity, air quality, and human safety. The function of the saprophytic fungus *Pleurotus citrinopileatus* (yellow golden oyster mushroom) in reducing forest fire hazards via efficient breakdown of leaf litter is examined in this work. The study underlines the need of forest management techniques including fuel removal strategies instead of conventional fire suppression techniques, therefore encouraging ecological balance and lowering of fire threats in the Wildland-Urban Interface (WUI).

With an eye towards thermogravimetric analysis (TGA) to analyze the thermal degradation characteristics of leaf litter, we carried out a series of tests to evaluate the cultivation of *P. citrinopileatus* utilizing leaf litter as a substrate. Analyzed key parameters such as ash concentration, thermogravimetric response, decommission temperatures, and ignition points to determine the combustibility and safety of leaf litter during burning. Our results show that *P. citrinopileatus* enzymatic activity improves organic matter content and recycles nutrients, therefore enhancing soil quality and perhaps helping to lower fire hazards related to litter accumulation.

Furthermore, discussed are the financial consequences of growing *P. citrinopileatus* from agricultural waste substrates, therefore stressing its possibilities for local economic growth and employment generation. This study emphasizes both environmental and financial advantages of including fungal growth into sustainable forest management techniques, therefore helping to maximize resource recovery and waste management techniques in forest environments.

Key words: Forest fires, *Pleurotus citrinopileatus*, Leaf litter decomposition, Fuel removal strategies, Thermogravimetric analysis (TGA).

Introduction

Forest fires are natural phenomena that help maintain forest ecosystems. However, the rising frequency and intensity of these fires pose serious threats to biodiversity, air quality, and human safety. Like many forested areas, this region is increasingly vulnerable due to climate change and human activity. Both natural (e.g., lightning, volcanic eruptions) and human-induced (e.g., poor land management, improper waste disposal) factors contribute to forest fires (Hood *et al*., 2024; Yap *et al*., 2023).

Fuel accumulation from fire suppression practices has altered natural fire regimes, raising the risk of catastrophic wildfires. Fires can disrupt ecosystems, causing biodiversity loss and severe air pollution due to smoke (Roon *et al*., 2025; Yap *et al*., 2023). Moreover, forest fires accelerate soil erosion, degrade water quality, and release large quantities of carbon dioxide, further intensifying climate change through a harmful feedback loop (Tahir *et al*., 2024; Yap *et al*., 2023).

To mitigate these impacts, fuel-removal strategies have gained attention, especially in the Wildland-Urban Interface (WUI). Unlike reactive fire suppression, fuel-removal proactively reduces surface fuels, lowers fire intensity, and enhances ecological stability without the need for specialized fire response teams (Chen *et al*., 2024; Daum *et al*., 2024; Nguyen *et al*., 2024). Studies have shown that treated stands demonstrate significantly reduced fire behavior indicators (Han Mei *et al*., 2018; He *et al*., 2023).

The saprophytic yellow golden oyster mushroom, *Pleurotus citrinopileatus,* is found in East Asia (Diamantis *et al*., 2024; Ghafoor & Niazi, 2024). This species is popular in cooking due to its bright yellow color and unique flavor (YE *et al*., 2024). Besides its culinary significance, *P. citrinopileatus* degrades lignocellulosic compounds well, making it important for environmental and economic uses (Parmar *et al*., 2024; Tao & Zheng, 2023; Yang *et al*., 2024).

By degrading forest litter, *P. citrinopileatus* helps reduce the combustible material on the forest floor, contributing to fire risk mitigation. Additionally, it can grow on a wide range of organic substrates, including agricultural residues such as straw and mushroom waste. This offers a sustainable and low-cost option for mushroom cultivation, supporting waste management and local economic development (Diamantis *et al*., 2024; Magh *et al*., 2024; Manimaran *et al*., 2024; Tao & Zheng, 2023).

Thermogravimetric analysis (TGA) is a reliable method for evaluating thermal stability and decomposition characteristics of organic substrates (Colleoni *et al*., 2025; Xue *et al*., 2022). It helps understand how fungal treatment alters the combustion behavior of leaf litter. This study uses TGA to assess the thermal degradation of leaf litter and investigates the potential of *P. citrinopileatus* cultivation as a strategy for wildfire mitigation and sustainable forest management (Shagali *et al*., 2025).

This study aims to explore the cultivation of *Pleurotus citrinopileatus* using leaf litter as a sustainable substrate, supported by thermogravimetric analysis to assess its suitability and implications. The primary objectives are:

1. To evaluate the potential of leaf litter as a nutrient-rich substrate for the efficient cultivation and yield improvement of *Pleurotus citrinopileatus*.
2. To analyze the thermal properties of leaf litter through thermogravimetric analysis, focusing on ash content, weight loss patterns, and key decomposition temperatures.
3. To determine the ignition characteristics of leaf litter, providing insights into its combustibility and implications for fire safety and forest management.
4. To assess the sustainability potential of using leaf litter in mushroom cultivation, emphasizing environmental and resource management benefits.
5. To examine the economic and ecological feasibility of this approach, highlighting its role in waste valorization and sustainable agricultural practices.

Material and Methods

Study area: The study took place at Northeast Forestry University Harbin's Birch Forests. (Fig. 1) shows the location of study area between 45°43.5331'N and 126°37.3797'E. Regional climate is cold temperate and affected by the continental monsoon. This climatic pattern produces short warm, humid summers and lengthy cold, dry winters. Study area receives 450–500 mm of precipitation annually, mostly from June to August. Despite summer rains, seasonal temperatures vary greatly. This region's harsh continental climate is reflected in its unusually low winter temperatures (-52.3°C) and high summer temperatures (31.6°C).

The mother species of *Pleurotus citrinopileatus* was provided by the Department of Forest Protection of Northeast Forestry University. Leaf litter was collected from the Birch Forest stands of Northeast Forestry University from mid-October to November 2023. Then the collected leaf litter was kept in a controlled natural environment to completely dry for 3 months. After drying litter was crushed and then kept for the preparation of mushroom's cultivation bags.

The cultivation of *Pleurotus citrinopileatus* (Golden Oyster Mushroom) in petri plates involved several steps to ensure successful mycelium growth. The agar medium (PDA) was prepared by mixing the appropriate amounts of agar with distilled water and autoclaved at 121°C for 15-20 minutes to sterilize. Approximately 20 ml of the molten agar was poured into each sterile petri plate and allowed to solidify (Herawati *et al*., 2024; MEDANY, 2014). Under sterile conditions within a laminar flow hood, the petri dish containing the solidified agar was opened. Using a sterilized tool a small piece of mushroom spawn was taken and placed onto the agar surface. The spawn was gently rolled around on the agar to distribute it evenly (Hassan *et al*., 2024; Herawati *et al*., 2024; MEDANY, 2014). The petri dishes were sealed securely and labeled with relevant information. The plates were incubated at a temperature conducive for mycelium growth at 20°C. Mycelium growth was monitored over the next 5 to 8 days (Herawati *et al*., 2024; MEDANY, 2014).

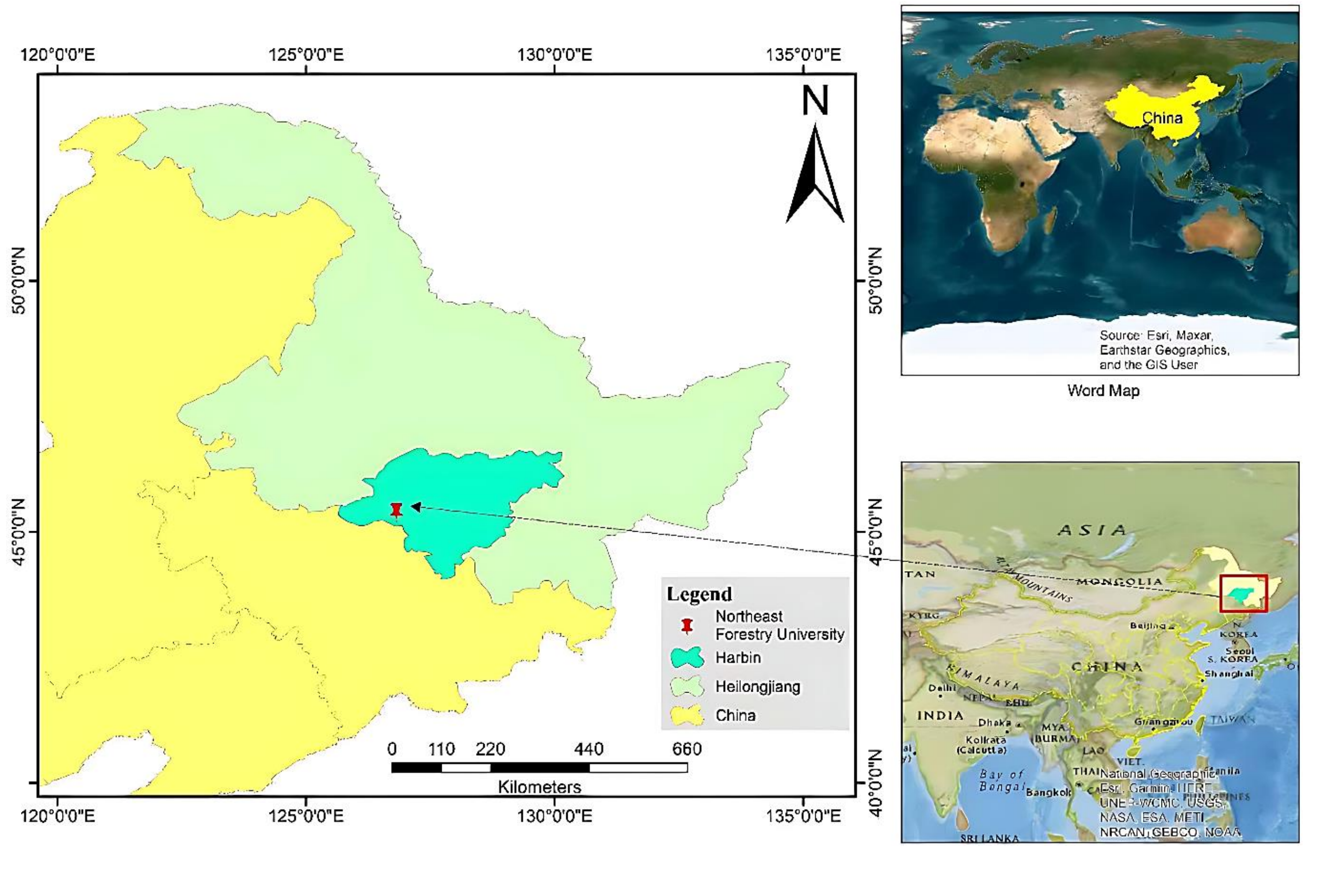

Fig. 1. Geographic location of the study area.

After about a week, the plates were checked for contamination and assessed for the density of mycelium growth. Healthy spawn showed vigorous white mycelium covering the agar surface (Herawati *et al*., 2024; MEDANY, 2014). After fully colonized, these plates were used for further inoculating cultivation bags. The PDA-cultured fungus was cut from each plate and transferred to a PD liquid medium. This medium was then placed in a shaker for 10 days to promote mycelium growth in the PD medium.

When prepared the culture bags for the yellow oyster mushroom, the total weight of each bag was 400 grams, of which 60% (240 grams) was water, and the remaining 40% (160 grams) contained leaf litter, sawdust, 1% lime, 1% corn flour, and 20% wheat bran. The ratio of leaf litter for 6 different cultivation bags was 0% for controlled group, 25%, 40%, 55%, 70% ,85% and 100% of the remaining 40% (160 grams) respectively. Once the cultivation bags were prepared, the next phase was inoculation. 100 mL of the prepared PD medium containing actively growing mycelium was poured into each culture bag designed for mushroom cultivation with the help of a pippet. This step was critical as it ensured that the mycelium could colonize the substrate uniformly, which is vital for healthy mushroom development.

Following inoculation, the bags were incubated under specific environmental conditions conducive to mycelium growth. The incubation room maintained a temperature range of 20-25°C and a humidity level between 70-85%. These conditions were essential for promoting rapid and healthy mycelial colonization. The bags were regularly monitored for signs of contamination and to ensure consistent mycelium colonization across all substrates. Any contaminated bags were promptly removed to prevent the spread of pathogens.

After successful incubation, conditions were adjusted to initiate fruiting. The temperature was slightly lowered, and light exposure was increased to simulate environmental natural cues that trigger fruit body formation. Humidity levels were maintained at a high range of 85-95% to support the development of fruiting bodies. This stage requires careful monitoring to optimize conditions for maximum yield. Once the mushrooms reached maturity, they were carefully harvested to avoid damaging the substrate. This ensured that subsequent flushes could occur without significant delay or reduction in yield.

Field experiment setup: Three cultivation bags with the 100%leaf litter substrate were made and placed in the Birch Forest of Northeast Forestry University. Six plots were selected: Two in dense canopy cover (F1 and C1), two in middle-aged birch stands (F2 and C2), and two in open areas with full sunlight exposure (F3 and C3). Each plot included one fungal cultivation bag and one controlled litter. This setup allowed for a comprehensive analysis of how fungal growth affected the litter layer across different environmental conditions. By integrating these analytical techniques and field experiments, the study provided valuable insights into optimizing mushroom cultivation for ecological benefits, particularly in wildfire prevention through enhanced litter decomposition. By enhancing the decomposition process, fungal bags could contribute to healthier forest ecosystems and mitigate fire risks. When the fungus was grown in the selected plots the litter from every plot was collected and brought back to the laboratory for the investigation of temperature comparison, thermogravimetric analysis (TG), fat content, higher heating values and ash percentage was examined to understand the effects of fungal growth on substrate decomposition and its role in wildfire prevention. The study compared controlled plots with fungal plots to assess these factors.

Temperature comparison: Temperature is a critical factor influencing both mushroom growth and substrate decomposition. Controlled experiments were conducted to compare temperature variations in fungal cultivation plots versus control plots. Previous studies have shown that maintaining optimal temperatures enhances mycelial activity, which can accelerate the breakdown of organic matter, potentially reducing fuel loads that contribute to wildfires (Chen *et al*., 2024; Lyons *et al*., 2006; Rukhiran *et al*., 2023a).

Thermogravimetric analysis (TGA): Thermogravimetric analysis (TGA) (Wang *et al*., 2025) was utilized to evaluate the thermal stability and decomposition characteristics of cultivation bags made entirely from 100% leaf litter. These bags were methodically placed in the Birch Forest at Northeast Forestry University, creating a controlled environment conducive to mushroom cultivation. Once the mushrooms had fully matured, the cultivation bags were retrieved and transported to the laboratory for in-depth thermogravimetric analysis. The TGA process measured weight loss patterns of the substrate under controlled heating, providing key insights into its thermal decomposition and the degree of organic matter breakdown. This approach proved invaluable in assessing the role of fungal activity in enhancing the decomposition rates of the leaf litter substrate. A comparative analysis with control plots, which lacked fungal colonization, further highlighted the efficacy of fungal activity in accelerating organic matter degradation. The findings revealed how the fungal-induced decomposition process could significantly reduce potential wildfire fuel loads in forest ecosystems, underscoring the environmental benefits of mushroom cultivation practices and their contribution to sustainable forest management (Chen *et al*., 2024; Lyons *et al*., 2006; Ślężak *et al*., 2018).

Fat content determination: The fat content of the samples was determined using a standard Soxhlet extraction method. A pre-weighed amount of the dried sample was finely ground and placed in a thimble. The thimble was inserted into a Soxhlet apparatus, and fat was extracted using petroleum ether as the solvent. The extraction process was carried out for approximately 6 hours, ensuring continuous reflux of the solvent. After extraction, the solvent was evaporated using a rotary evaporator, and the remaining fat was dried in an oven at 105°C to remove any residual solvent. The fat content was calculated as a percentage of the initial sample weight. This method ensured precise and consistent determination of fat content in all tested samples (Chen *et al*., 2024; Gesese *et al*., 2025; Lyons *et al*., 2006).

Table 1. Overview of equipment used for common analytical measurements.

Analysis type	Equipment	Models
Thermogravimetric Analysis (TGA)	Thermogravimetric Analyzer	TA Instruments TGA series, NETZSCH STA, Mettler Toledo TGA
Ash Content Measurement	Muffle Furnace	Carbolite Gero CWF series, Thermo Fisher muffle furnaces
Fat Content Measurement	Soxhlet Extractor and Automated Fat Extractor	Soxtec Systems by Foss, Buchi Extraction Systems
Ignition Point Measurement	Ignition Point Tester	Pensky-Martens Flash Point Tester, Cleveland Open Cup Tester
Higher Heating Value (HHV) Measurement	Bomb Calorimeter	Parr Instrument Bomb Calorimeters, IKA Calorimeters

Ash percentage: Determination of Ash The ash content (Ash %) is usually measured using the dry ashing method. To implement the method, the procedure is as follows: put the sample through 60-mesh sieves into a crucible, cover it with a lid to isolate the air, ash it at 500◦C in a JXL-620 intelligent integrated muffle furnace for 12 h, ensure it is completely ashed to constant weight, and subtract the weight of the crucible (the ash content of the sample) (Chen *et al*., 2024; Gesese *et al*., 2025; Ślężak *et al*., 2018) (Table 1).

$$A\% = \frac{m_3 - m_1}{m_2 - m_1} \times 100\%$$

In the formula, m_1 is the weight of the crucible, g; m_2 is the weight of the crucible and sample before combustion, g; and m_3 is the weight of the crucible and sample after combustion, g.

Determination of higher heating value and ash-free calorific value: A microcomputer oxygen–nitrogen calorimeter, model XRY-1C, was used to measure the sample's higher heating value (HHV). A total of 1 g of the dried sample was weighed and pressed into a block and then continued to dry until the weight was constant to ensure the moisture was completely removed. Then, the mass of the sample was accurately weighed (to the nearest 0.0001 g) using an analytical balance to determine its higher heating value (Gomez-Vasquez *et al*., 2025). Three replicates were used for each sample to obtain the average value. The unit used for the higher heating value and ash-free calorific value is $KJ \cdot g^{-1}$. The ash-free calorific value (AFCV) is calculated as follows:

$$\text{AFCV} = \frac{\text{HHV}}{(1 - \text{A})}$$

By integrating these analytical techniques and field experiments, the study provided valuable insights into optimizing mushroom cultivation for ecological benefits, particularly in wildfire prevention through enhanced litter decomposition.

Results

Days for mushroom growth stages in different substrates: The control substrate demonstrated superior performance in the growth stages of *P. citrinopileatus* compared to leaf-based substrates as shown in (Fig. 2). It completed spawn running in just 18 days, pinhead formation in 20 days, and fruiting body formation in 30 days, which were the shortest durations recorded. In contrast, leaf-based substrates required more time, with delays ranging from 2 to 15 days depending on the proportion of leaves. This indicates that the control substrate provided the most favorable conditions for faster mycelial colonization and fruiting body development.

Average number of fruiting bodies: It can be seen in (Fig. 3) the control substrate 0% also yielded the highest number of fruiting bodies, averaging 45. While the 55% leaf substrate performed relatively well with 40 fruiting bodies, it still did not surpass the control group. Substrates with higher leaf content, such as 70%, produced significantly fewer fruiting bodies, averaging just 25. These findings suggest that excessive leaf content can negatively affect fruiting efficiency, likely due to an imbalance in nutrients or unfavorable physical properties of the substrate.

Weight of fruiting bodies: In terms of fruiting body weight, as shown in (Fig. 3) the control substrate 0% again outperformed the others, producing the heaviest fruiting bodies at 120.7 grams. The 55% leaf substrate followed with a respectable 100.2 grams but could not match the control. Substrates with 70% leaves performed the poorest, with fruiting bodies weighing only 65.6 grams on average. This highlights that the control substrate is the most effective for achieving heavier and higher-quality fruiting bodies in the cultivation of *Pleurotus citrinopileatus*.

Statistical Analysis

A one-way ANOVA revealed a significant effect of substrate type on mushroom growth metrics, F (5,36) =33.81, p<.001, F (5,36) =33.81, p<.001 (Table 2). This indicates that at least one substrate treatment resulted in significantly different outcomes.

The heatmap in (Fig. 4) provides a clear visual representation of the data, showing how various metrics vary across different groups. Each row represents a group, while the columns display metrics. Darker colors indicate higher values, making it easy to spot trends. For instance, "Fruiting Bodies in gm" stands out with the highest values across most metrics, including a very large variance (800.26), which shows significant variability in this category. On the other hand, "Substrate" has the smallest values and the least variation (variance = 0.1214), suggesting consistent data for this group. The time-related groups, like "Days of completing spawn running," "Days of pinhead formation," and "Days of fruiting body formation," show a natural progression, with their sum and average values increasing as the stages advance. Overall, the heatmap highlights key differences between the groups, emphasizing the dominance of "Fruiting Bodies in gm" and the stability of "Substrate."

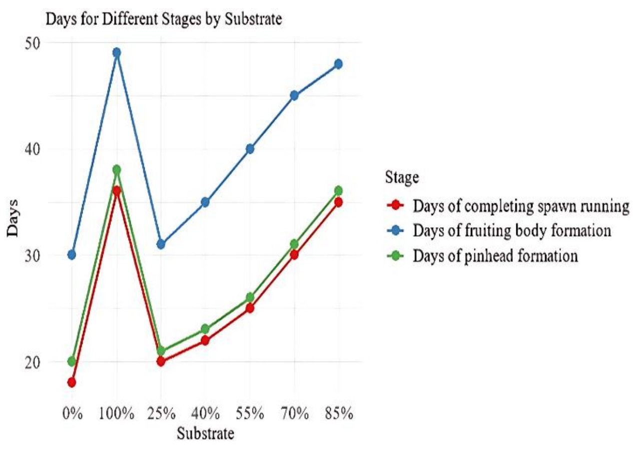

Fig. 2. Days for mushroom growth stages by different substrate.

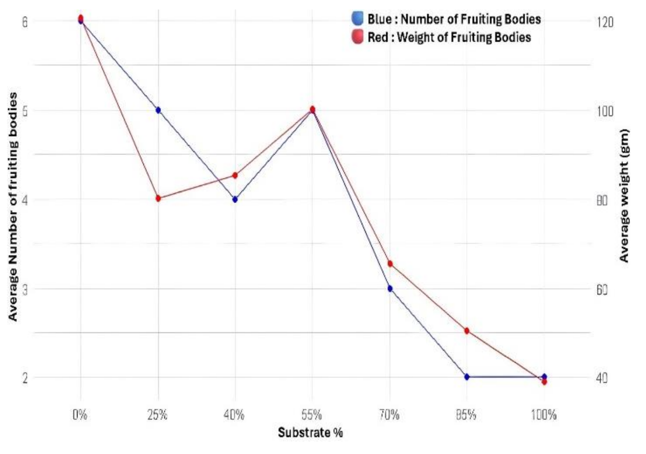

Fig. 3. Average number and weight of fruiting bodies.

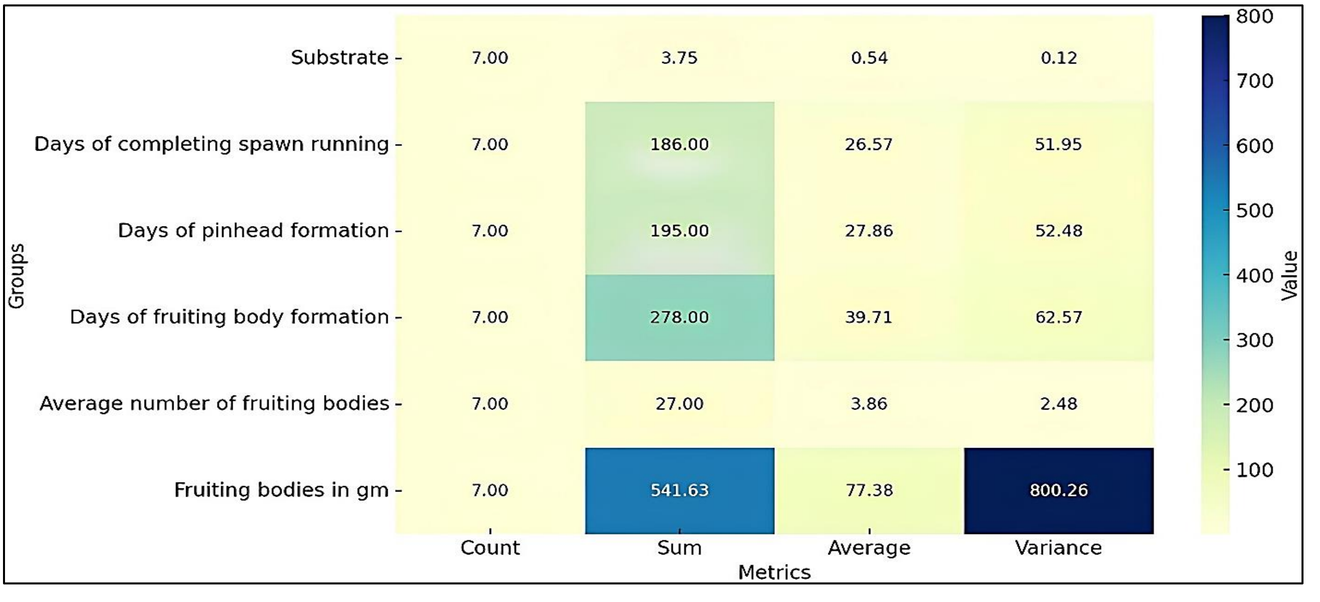

Fig. 4. Heatmap for single factor ANOVA analysis.

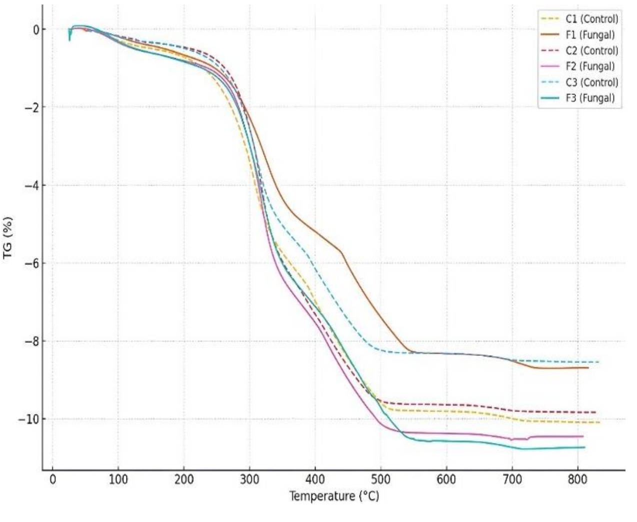

Fig. 5. TGA Analysis.

Thermogravimetric analysis (TGA) results: It can be seen in (Fig. 5) that the TGA analysis shows distinct differences between the control samples (C1, C2, C3) and the fungal-grown samples (F1, F2, F3). The fungal samples demonstrate a faster rate of mass loss, indicating reduced thermal stability. This suggests that fungal activity alters the chemical structure of the litter, causing it to decompose more quickly at lower temperatures. Consequently, fungal-grown litter may ignite more easily than controlled litter. However, this rapid decomposition also means that the fuel available for sustained burning is reduced, potentially limiting the overall spread of wildfire.

Ash content: The fungal samples as shown in (Fig. 6) have consistently higher ash content (F1: 13.14%, F2: 7.20%, F3: 7.47%) compared to the control samples (C1: 7.47%, C2: 3.64%, C3: 4.09%). Since ash is non-combustible, its presence helps reduce the amount of material available for burning. The increased ash content in fungal samples makes them less likely to sustain combustion, which is a favorable characteristic for reducing wildfire risks.

Fat content: Fig. 6. illustrates that the fat content, which contributes to a material's flammability, varies between the control and fungal samples. In some cases, such as F2 (3.41%), the fungal samples have lower fat content than the controls (C2: 4.55%), reducing their flammability.

However, in other cases, such as F1 (11.18%), the fat content is slightly higher than the corresponding control (C1: 10.47%). While fungal activity can reduce fat content and flammability in some instances, the results are not entirely consistent across all samples.

Ignition point: The ignition points, which indicate the temperature at which a material begins to burn, vary slightly between the control and fungal samples as shown in (Fig. 6). The control samples generally have higher ignition points (C1: 256°C, C2: 249°C, C3: 248°C) compared to fungal samples (F1: 258°C, F2: 245°C, F3: 247°C). While F1 shows a slight improvement, F2 and F3 have lower ignition points, making them slightly more prone to ignition. On average, the control samples demonstrate a marginal advantage in ignition resistance.

Higher heating value: It can be seen in (Fig. 6) that the higher heating value (HHV), which measures the energy released during combustion, is consistently lower in fungal samples (F1: 18,533.9 J/g, F2: 16,844.8 J/g, F3: 17,097.4 J/g) compared to controls (C1: 17,930.4 J/g, C2: 19,064.3 J/g, C3: 19,030.4 J/g). A lower HHV indicates less energy is released during burning, which reduces the intensity and potential spread of a fire. This makes fungal-grown litter less likely to contribute to large or intense wildfires.

Statistical Analysis

We used Welch's t-test and the Wilcoxon rank sum test, along with effect size calculations, to analyze the data (Table 3).

Comparison of ash, fat, heating value, and ignition point through Welch's t-test and Wilcoxon Rank Sum Test: The Fungal treatment showed a trend towards higher Ash content, with a large effect size (Cohen's d = -1.020, Cliff's delta = -0.667). While not statistically significant, this increase in ash is a positive indicator from a wildfire prevention standpoint. More ash means less material available to burn, potentially reducing fire intensity and spread.

The results for Fat content were less clear. The effect sizes were small (Cohen's d = 0.339, Cliff's delta = 0.333), suggesting little practical difference between the groups. Therefore, the fungal treatment did not appear to have a substantial impact on this property relevant to wildfire prevention.

The Fungal treatment also showed a trend towards a higher Heating Value, with a medium effect size (Cohen's d = 0.537, Cliff's delta = 0.333). From a wildfire prevention perspective, a higher heating value is generally not desirable, as it indicates that the fuel releases more energy when burned. However, the lack of statistical significance and the moderate effect size suggest this increase may not be practically meaningful and requires further investigation.

The Fungal treatment showed a trend towards a higher Ignition Point, with a medium effect size (Cohen's d = 0.655, Cliff's delta = 0.333). A higher ignition point is beneficial for wildfire prevention, as it means the treated material is less likely to ignite. Although not statistically significant, this trend suggests the fungal treatment could potentially reduce the ignitability of the fuel.

The heatmap in (Fig. 7) visually summarizes the results from Welch's t-test, Wilcoxon rank sum test, and effect size calculations for the variables "Ash," "Fat," "Heating," and "Ignition." Each column represents a specific metric, such as estimates, adjusted p-values, test statistics, and effect sizes (Cohen's d and Cliff's delta). Darker shades indicate higher values, while lighter shades reflect lower ones. Among the variables, "Heating" stands out with the highest estimate t-value (1245.267), whereas "Ash" shows negative values for both its estimate (-3.111) and effect sizes (Cohen's d = -1.020, Cliff's delta = -0.667), highlighting its unique behavior compared to the others. The adjusted *p*-values are consistent throughout the tests, remaining close to 0.699 or 0.700. Overall, the heatmap effectively captures key patterns, such as the strong effects associated with "Ash" and the prominence of "Heating," making it easier to interpret the statistical and practical significance of the data.

Table 2. Statistical analysis.

Groups	Count	Sum	Average	Variance
Substrate	7	3.75	0.535714	0.121429
Days of completing spawn running	7	186	26.57143	51.95238
Days of pinhead formation	7	195	27.85714	52.47619
Days of fruiting body formation	7	278	39.71429	62.57143
Average number of fruiting bodies	7	27	3.857143	2.47619
fruiting bodies in gm	7	541.63	77.37571	800.2594

ANOVA

Source of variation	SS	df	MS	F	P-value	F crit
Between Groups	27327.86	5	5465.571	33.81264	1.21E-12	2.477169
Within Groups	5819.142	36	161.6428			
Total	33147	41				

Table 3. Welch's t-test and the Wilcoxon rank sum test.

Variable	Estimate t	P adjusts BH t	Statistic t	P adjust BH w	Statistics w	Cohens d	Cliffs delta
Ash	-3.111	0.699	-1.758	0.600	3	-1.020	-0.667
Fat	1.041	0.699	0.547	0.700	5	0.339	0.333
Heating	1245.267	0.699	0.824	0.700	4	0.537	0.333
Ignition	2.333	0.699	1.000	0.700	4	0.655	0.333

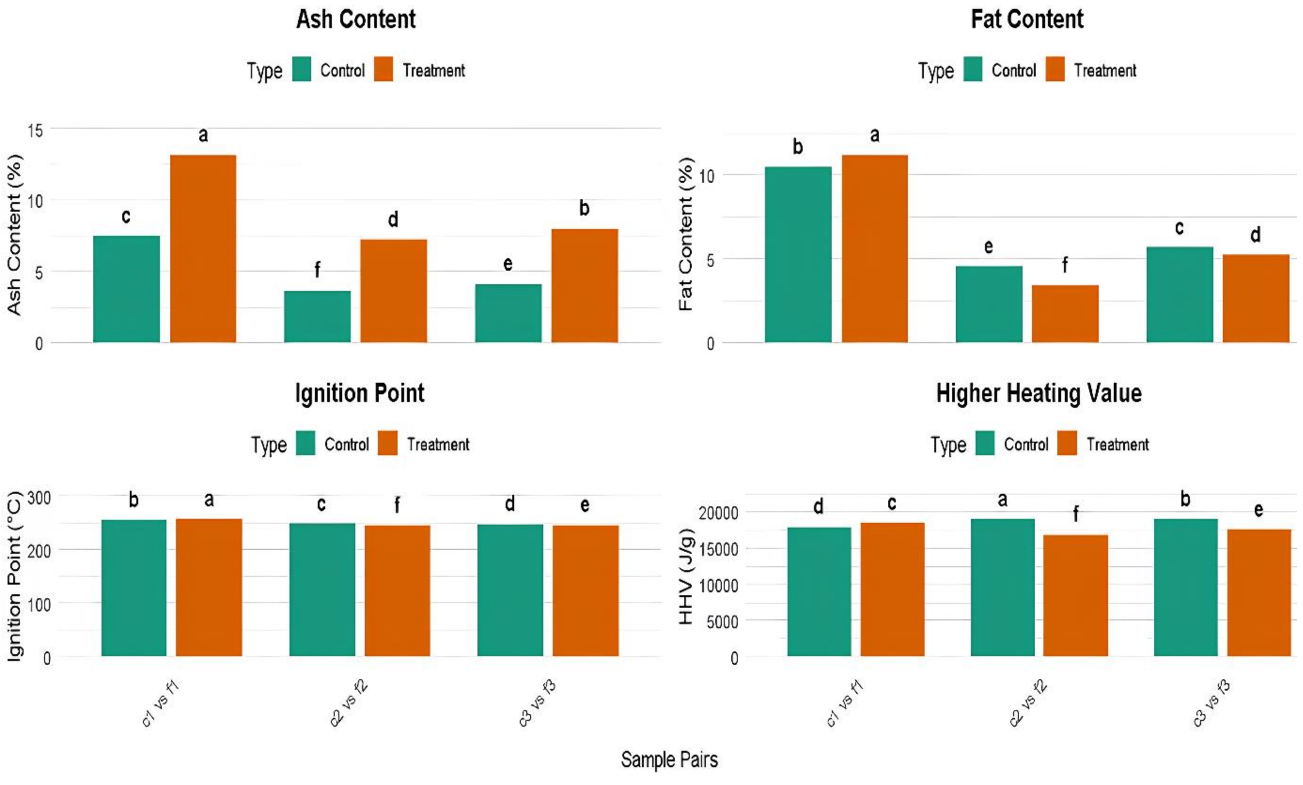

Fig. 6. Determination of ash content, fat content, ignition point and higher heating values.

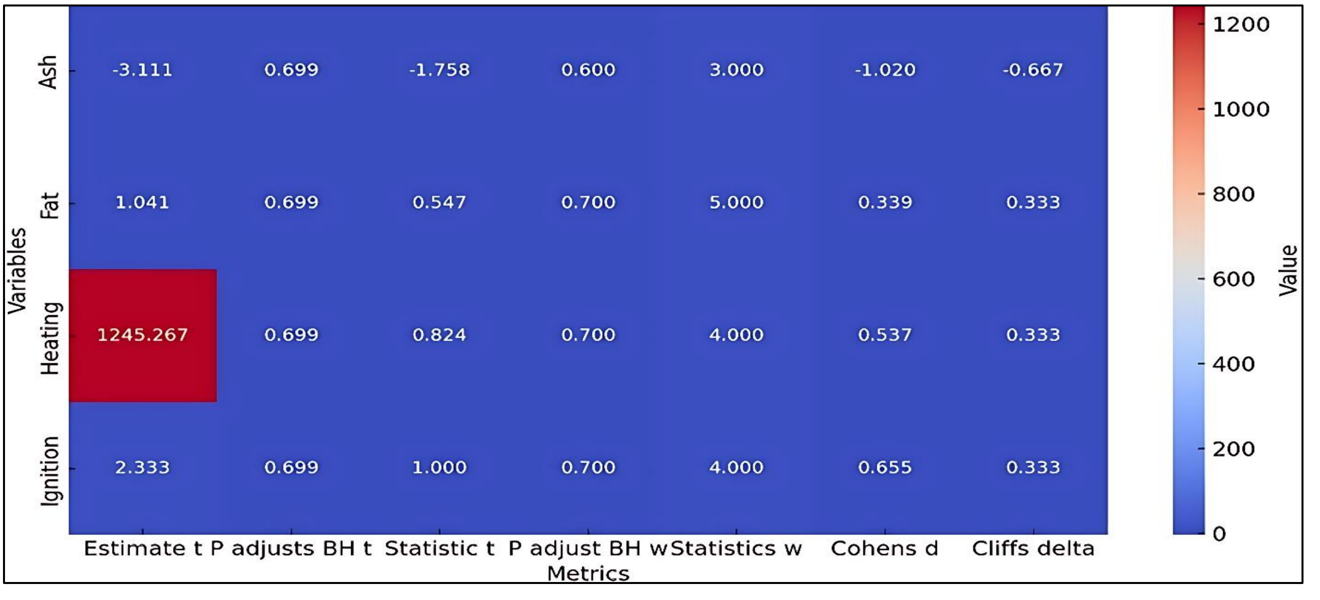

Fig. 7. Heatmap for Welch's t-test and the Wilcoxon rank sum test.

Discussion

The results of this work highlight the ecological advantages and pragmatic consequences of applying *P. citrinopileatus* for leaf litter breakdown in regions prone to wildfires. Our thermogravimetric investigation demonstrated improved breakdown rate and changed thermal characteristics of fungal-treated leaf litter that match results of earlier studies investigating fungal enzymatic activity in lignocellulosic degradation.

For instance, (Gomez-Vasquez *et al*., 2025) underlined how effectively *P. citrinopileatus* breaks down complex organic components into simpler forms, therefore improving soil nutrient content and lowering fire risk. Our findings of higher ash concentration in fungal-treated leaf litter line well with the work of (Slezak *et al*., 2018), who showed that fungal activity greatly increases the inorganic residue in decomposing substrates. Ash is non-combustible; hence its rise helps to lower the material availability for burning, thereby reducing the risk of ongoing wildfires. This result strengthens (Chen *et al*., 2024), who underlined that in forest ecosystems, higher ash content corresponds with reduced fuel combustibility. Although our investigation revealed variations in fat content and ignition points across fungal-treated samples (Gesese *et al*., 2025), who observed that the thermal behavior of treated materials is much influenced by substrate composition and fungus species somewhat supports these findings. Such diversity points to the need for further improvement of substrate formulations to standardize the results of fungal treatments.

Fungal-treated substrates displayed a lower heating value (HHV), suggesting less energy release after combustion than untreated control samples. This is consistent with results of (Xue *et al*., 2022), who found that fungal breakdown of lignocellulosic materials lowers the calorific value, hence less likely to be prone to high-intensity flames. Furthermore, our findings on ignition sites align with those of (Ilias Diamantis *et al*., 2024), who noted that the ambient circumstances and substrate composition might either raise or lower ignition resistance. Regarding ecological and financial possibilities, *P. citrinopileatus's* capacity to flourish on leaf litter is compatible with studies by (YE *et al*., 2024), who highlighted the adaptability of this fungus to diverse substrates, including who underlined the flexibility of this fungus over several substrates, including agricultural byproducts. By growing high value mushrooms, this adaptation not only aids local economies but also effective waste recycling. Such financial gains fit more general sustainability objectives stressed in (Rukhiran *et al*., 2023b)'s work on IoT-based mushroom farming systems.

Results from (Iglesias *et al*., 2025; Lyons *et al*., 2006) who underlined the need of microclimatic conditions in fungal development and litter breakdown match the influence of environmental elements, such as canopy cover and sunshine exposure, in determining fungal colonization and rates of decomposition. Our field studies confirm these findings and underline the need to customize fungal based therapies to site specific circumstances. By offering fresh insights on the thermal and compositional changes caused by *P. citrinopileatus* in forest litter, our work broadens upon previous studies. These results confirm the possibility of including fungal-based decomposition techniques into forest management strategies to attain ecological sustainability and decrease wildfire risk.

Economically, the cultivation of *P. citrinopileatus* on leaf litter offers a low cost and sustainable alternative to conventional substrates such as sawdust or wheat straw, which often require processing, transport, or purchase. Leaf litter is abundantly available as a natural forest byproduct and typically incurs no cost, making it an economically attractive substrate, particularly in resource constrained or rural areas. While the yield and fruiting body weight on pure leaf litter were slightly lower than those on optimized mixed substrates, the reduced input costs and ease of availability offset the marginal drop in productivity. Furthermore, using leaf litter not only minimizes substrate costs but also adds value to an otherwise discarded forest residue, aligning with circular economic principles. Based on these findings, we recommend the integration of leaf litter as a primary or partial substrate for *P. citrinopileatus* cultivation, particularly in forest-edge communities where litter collection can be coupled with wildfire prevention strategies. This dual benefit economic viability and ecological risk mitigation makes leaf litter a strategic substrate choice for scalable and sustainable mushroom farming.

Conclusion

This paper emphasizes the ecological and financial possibilities of *P. citrinopileatus* farming as a creative method of sustainable forest management and wildfire risk reduction. Using the enzymatic capacity of this saprophytic fungus, we show a notable increase in the breakdown of leaf litter, a major source of forest fire fuel load contribution. Together, the fungal-treated substrates showed lower heating values, increased ash content, and decreased thermal stability, thereby indicating a reduced potential for continuous combustion. These developments highlight the possibility of fungal-based approaches to efficiently lower flammability and lower wildfire hazards. Emphasizing the need of site-specific applications, field experiments also showed that environmental elements, such canopy cover and sunlight exposure, greatly affect fungal colonization and breakdown efficiency. Furthermore, the economic viability of *P. citrinopileatus* farming on leaf litter creates opportunities for combining resource recovery and trash management, therefore supporting local employment and economic development. Using fungal-based fuel reduction strategies provides a reasonably affordable, ecologically friendly substitute that fits with sustainability and biodiversity preservation as compared to traditional fire suppression methods. Nevertheless, seeing variations in fat content and ignition resistance between substrates emphasize the need of more study to standardize and maximize substrate compositions for best performance. Finally, the combined use of *P. citrinopileatus* farming into forest management strategies has great potential to solve the two issues of ecological restoration and wildfire prevention. To maximize environmental and financial gains, future studies should concentrate on improving these techniques and increasing their relevance over several forest habitats.

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