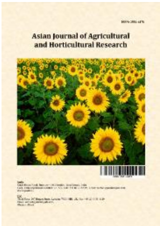

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Duration of Light Exposure Using White Light-Emitting Diode (LED) on the Performance of White Oyster Mushroom (*Pleurotus ostreatus* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: In the dynamic world of mushroom cultivation, optimizing growth conditions is paramount for maximizing yield and quality. This research sought to evaluate the influence of varying hours of exposure to white light through light-emitting diodes (LED) on growth and yield performance of white oyster mushroom (*Pleurotus ostreatus* L.). Its aim was to determine the most effective light exposure duration for enhancing mushroom growth and yield.

Research Design: Using a completely randomized design (CRD), the study used four treatments: 8 hours of lighting (T1), 12 hours of lighting (T2), 16 hours of lighting (T3), and a control group that

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received natural light (T4). The study was conducted in Palayamanan (8° 27’ 5.3118" N and 126° 9’ 59.7739" E) area at North Eastern Mindanao State University’s -Tagbina Campus from July 2023 to November 2023.
Results: Results from the study provided interesting insights into the indirect nature of the relationship between light exposure and mushroom development. The findings of the study indicate that the duration of light exposure significantly affects the growth and yield of white oyster mushrooms. Both mycelium growth (29.80 days) and fruiting body formation (7.83 days), as well as harvesting time (10.87 days), were improved by 12 hours of lighting, while the control group consistently showed poor performance.
Conclusion: Based from the analysis, it is evident that 12 hours of lighting consistently performed very well, with the exception of a minor under-performance in the case of yield per harvest, suggesting that 12 hours might be the ideal duration. Hence, 16 hours of lighting also demonstrated some advantages in certain variables, indicating potential for further study.

Keywords: White oyster mushroom; white LED light; growth performance; light duration.

1. INTRODUCTION

Mushroom cultivation is an important agribusiness and has gained significant attention in recent years due to its nutritional value, medicinal properties, and economic benefits. Among the cultivated mushroom varieties, white oyster mushroom (*Pleurotus ostreatus* L.) is one of the most popular due to its high nutritional content, delicious taste, and potential health benefits [1,2]. In the Philippines, oyster mushroom production is relatively small-scale, with an annual output of around 200 metric tons. This production is primarily driven by small-scale growers, contributing to a limited but steady supply in the market [3]. The oyster mushroom market is expanding significantly on a global scale. The market was estimated to be worth USD 56.13 billion in 2023 and is expected to rise at a compound annual growth rate (CAGR) of 7.8% to reach USD 102.37 billion by 2031. The rising demand from consumers for wholesome and environmentally friendly food options is driving this expansion [4].

To ensure optimal production of oyster mushroom, it is essential to understand the environmental factors that affect its growth and yield performance [1,2]. Light is a critical environmental factor for mushroom growth and development, and it has been extensively studied in the context of oyster mushroom cultivation. Light is essential for fruiting body induction and differentiation in mushrooms, including oyster mushrooms. The authors further noted that light duration and intensity can impact the morphological characteristics, biochemical composition, and overall yield of oyster mushrooms [5]. Additionally, light conditions during cultivation can significantly impact the nutritional content of white oyster mushrooms affecting riboflavin and thiamine contents [4]. Proper light management can significantly influence the success of mushroom cultivation, making it a key area of focus for researchers and cultivators alike.

Moreover, the length of the light period is a decisive factor for obtaining high yields of good quality fruiting bodies in oyster mushrooms [1,6]. Optimal light duration can promote the formation of primordia, enhance mycelial growth, and improve the quality and nutritional value of oyster mushrooms [2]. Fuller et al. [7] reported that inadequate light conditions can lead to poor-quality fruiting bodies, reduced yields, and changes in biochemical composition in oyster mushrooms. Conversely, the thiamine content tends to decrease with reduced light exposure [6]. Therefore, understanding the specific light requirements for oyster mushrooms is crucial for maximizing their production and ensuring high-quality yields. Hence, this study investigated the effects of different white LED lighting durations on the growth and yield performance of white oyster mushroom (*Pleurotus ostreatus* L.). By manipulating light duration, the study aimed to improve white oyster mushroom production and enhance its economic value. The findings of this study can contribute to the development of more efficient and sustainable white oyster mushroom cultivation practices, benefiting the agribusiness sector and promoting the wider adoption of mushroom cultivation as a viable agricultural practice.

2. MATERIALS AND METHODS

2.1 Experimental Design and Treatments

The study was carried-out using Completely Randomized Design (CRD) with four (4) treatments and replicated three (3) times. The treatments were expressed in duration of light, these were; Treatment 1 - 8 hours, Treatment 2 - 12 hours, Treatment 3 - 16 hours, and Treatment 4 - Natural light.

2.2 Site Selection

The study was conducted in Palayamanan (8° 27' 5.3118" N and 126° 9' 59.7739" E) area at North Eastern Mindanao State University's - Tagbina Campus from July to November 2023. The location was selected for its easy access and the availability of necessary resources for the research. The room was divided into four separate chambers for mushroom cultivation, representing the treatment and subdivided into three representing the replication. These chambers were designed to avoid external factors, such as; wind, and dust, preventing from contamination and maintain consistent experimental conditions. The dimensions, positioning, and alignment of the chambers were strategically determined to maximize natural lighting and minimize undesired temperature variations.

2.3 Construction of Cultivation Room and Installation of White LED Lights

The structure utilized in this study was built from wood and tarpaulin, measuring 3.5 meters in length and 1.5 meters in width. Each treatment area contained white LED lighting equivalent to an 18-watt fluorescent lamp covering the entire room. Each chamber could hold 60 fruiting bags of white oyster mushrooms, divided into three (3) replications with each replication contains 20 bags per treatment. Six white LED lighting installations were set up, two in each designated chamber, with exposure times controlled at 8, 12, and 16 hours to ensure uniform light exposure for all samples. The duration of light exposure was tailored to fit the experimental design. The chambers were designed for easy accessibility while ensuring adequate security and privacy.

2.4 Preparation and Inoculation of the Mushroom Fruiting Bags

The substrates of the mushroom fruiting bags were a mixture of 78% rice straw and 20% sawdust, 1% limestones and 1% brown sugar. The substrate was placed into polypropylene plastic bags measuring 6x12x0.02 inches, which were securely sealed with a rubber band. The mushroom fruiting bags were then sterilized for to ensure optimal growing conditions. Mushroom spawn was obtained from a reputable source, and the inoculation process was conducted aseptically. The procedure began with the sterilization of a flat-end needle in a flame, followed by stirring the grain spawn with it. A sterilized fruiting bag was then carefully opened, and 10g of grains were gently added to the bag. The newly inoculated bag was slightly tilted using PVC ring to evenly distribute the spawn in the shoulder area near the neck of the bag. This method ensured proper inoculation of the mushroom spawn within the fruiting bags, minimizing the risk of contamination and maximizing potential yield.

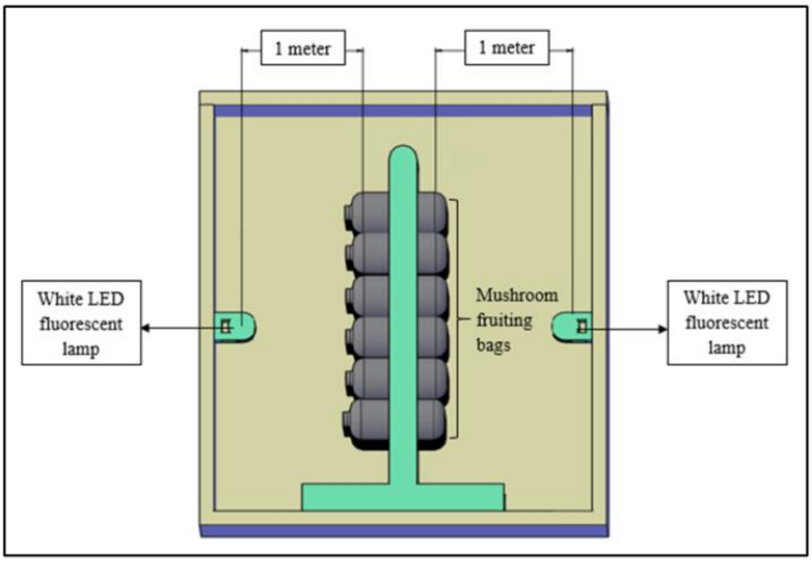

Fig. 1. Perspective view of mushroom cultivation room

2.5 Introduction of Fruiting Bags to Growth Chambers

In each growing chamber, a total of sixty (60) fruiting bags, in each replication contains twenty (20) bags per treatment, were introduced. Each bag, showing full mycelial growth, was strategically positioned to follow to the controlled light exposure times of 8, 12, and 16 hours. This arrangement was meticulously planned to guarantee consistent light exposure for all samples, facilitating uniform growth conditions across the treatments.

2.6 Pre-Harvest Handling Protocol

To ensure optimal fruiting, harvesting, and yield, the following protocol was implemented: The fruiting bags were regularly inspected for signs of mycelial growth until fruiting bags were completely covered. At this stage, the fruiting bags were slit using a cutter. The collected data were recorded, converted to CSV format and analyzed to assess the impact of light exposure duration on the growth and yield of white oyster mushrooms.

2.7 Harvesting

Fruiting bodies were monitored and harvested when the caps were fully mature. Harvesting was done every other day or two days interval until the fifth harvest, maintain the quality of the mushrooms. Fruiting bodies were removed from the bags by gently twisting and pulling them from the substrate to avoid damaged. The bags were misted with cleaned water every after harvest to the next flush.

2.8 Data Gathered

Various growth and yield traits viz., days taken to full mycelial growth, days taken to fruiting body formation, days taken to first harvest, cap diameter (cm), number of fruiting bodies formed, and fresh weight (kg) of mushroom fruiting bodies, were recorded.

2.9 Statistical Analysis

The data gathered were tabulated using Microsoft Excel converted into Comma-Separated Values (CSV) before further analyzed using Statistical Tool for Agricultural Research (STAR) version 2.0.1, it was summarized and organized using the Analysis of Variance (ANOVA) in a Completely Randomized Design (CRD). Significant difference in treatment means was further investigated utilizing Least Significant Difference (LSD) Test at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Days Taken to full Mycelial Growth

The production of fruiting bodies and overall yield are directly impacted by mycelial growth, which is an essential stage in the mushroom cultivation process [8,9]. With a mean mycelial development period of 29.80 days, 12 hours of light exposure is the most effective treatment (Fig. 2). This remarkable finding implies that mycelial development can be markedly accelerated by a particular length of light exposure. Following closely behind are 16 hours and 8 hours of light exposure, with mean durations of 29.90 days and 30.37 days, respectively. These findings indicate that while both shorter and longer durations of light exposure can still facilitate mycelial growth, there might be an optimal range within which the process is most efficient [10]. According to Halabura et al. [9], optimizing light conditions is essential for enhancing mushroom cultivation. Conversely, natural light, with a mean duration of 33.33 days, demonstrates the longest duration for mycelial growth. This result is particularly noteworthy, suggesting that natural light conditions may not be as conducive to mycelial growth compared to artificial light regimes. Such findings could have significant implications for mushroom cultivation practices, highlighting the potential benefits of controlled lighting environments. The current findings in mushroom cultivation are consistent with those of Glukhova et al. [8] and Halabura et al. [9], reinforcing the importance of light exposure in optimizing mycelial growth.

3.2 Days Taken to Fruiting Bodies Formation

The shortest duration for fruiting body formation was observed with 12 hours of light exposure, with a mean of 7.83 days. This suggests that a 12-hour duration of light exposure can promote faster fruiting body development compared to 8 hour or 16-hour light duration [11]. While 16 hours and 8 hours still facilitate relatively rapid fruiting body formation, the slightly longer duration of 8 hours compared to 12 hours implies that there may be an optimal threshold for light exposure that maximizes this process [12]. Interestingly, contrary to the study results, Zhang et al. [13] found that a longer light duration of 16 hours per day resulted in higher mycelial growth rates and increased fruiting body formation compared to a shorter light duration of 12 hours per day for the same mushroom species. However, statistically, there is no significant difference between 12 hour and 16 hours of light exposure in terms of fruiting body formation.

3.3 Days Taken to First Harvest

Among the treatments (Fig. 2), 12 hours exhibited the shortest duration to first harvest, with a mean of 10.87 days, comparable to 8 hours, which had a mean of 10.90 days. This suggests that a shorter or moderate duration of LED light exposure can effectively accelerate the maturation process, leading to earlier harvests. On the other hand, the longest duration to first harvest was observed under natural light (control). For instance, a study by Mykchaylova et al. [14] investigated the impact of different light regimes on the growth and yield of the edible medicinal mushroom, *Hericium erinaceus*. Their findings align with the study results, indicating that 12 hours of light duration promotes faster growth and a shorter time to first harvest. Similarly, Halabura et al. [9] explored the effects of light intensity and duration on mushroom cultivation, noting that adequate light exposure accelerates the maturation process, leading to earlier harvests.

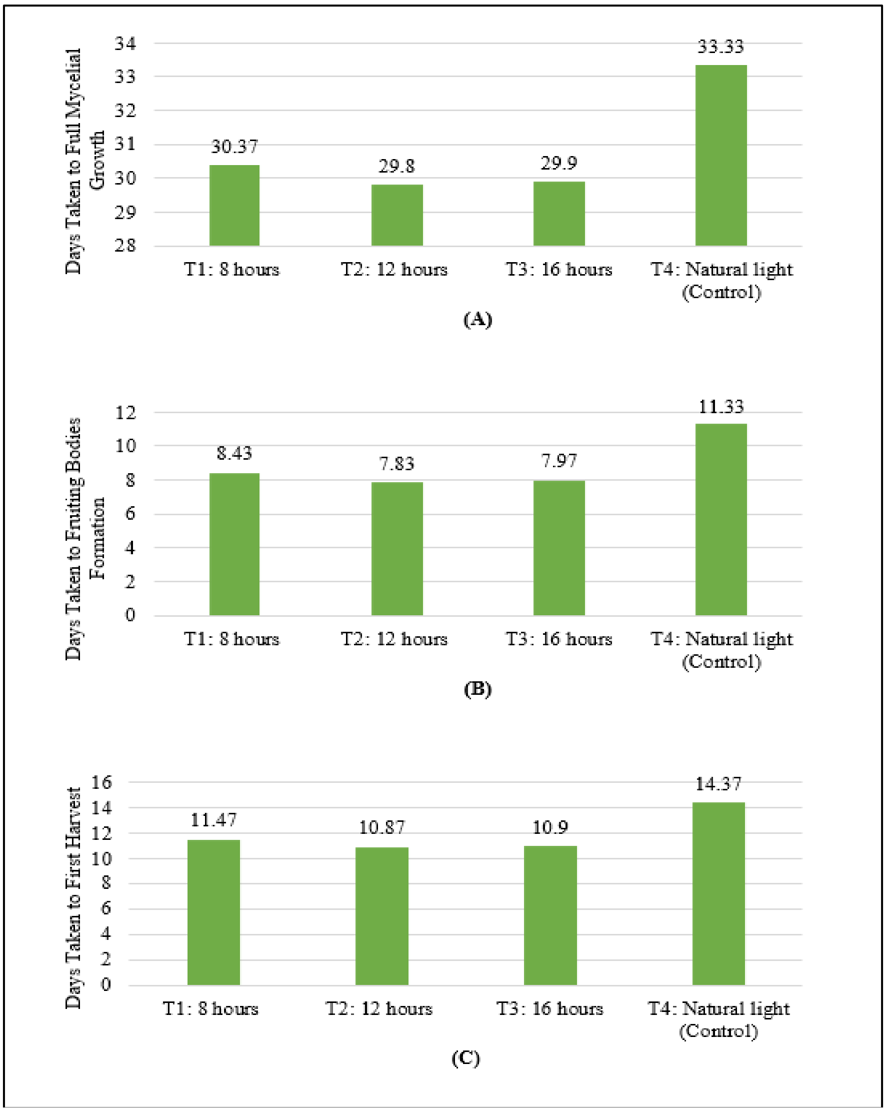

Fig. 2. Days taken for full mycelial growth (*A*), fruiting bodies formation (*B*) and first harvest (*C*) of white oyster mushroom (*Pleurotus ostreatus* L.) under varying duration using white light-emitting diode (LED)

3.4 Cap Diameter (cm) of Fruiting Bodies

Statistical analysis shows no significant difference among treatments, indicating that light duration may not directly impact the cap diameter (Table 1) of white oyster mushrooms. However, intriguing patterns emerge from the data. During the initial harvest, 16 hours of light exposure consistently boasted the widest cap diameter among all treatments, with means ranging from 5.87 cm to 6.37 cm across succeeding harvests. This trend suggests the potential of prolonged light exposure to foster larger cap diameters during the early stages of mushroom development. Following closely behind, 12 hours demonstrated comparable cap diameters to 16 hours, suggesting that moderate light duration also supports favorable growth outcomes.

On the other hand, 8 hours of light exposure exhibited narrower cap diameters, implying that shorter light duration may marginally inhibit cap development. Interestingly, natural light (control) consistently showed narrower cap diameters across all harvests, indicating that the absence of controlled lighting adversely affects cap growth. This observation aligns with the findings of Zawadzka et al. [6] and Halabura et al. [9], emphasizing the crucial role of light in promoting optimal mushroom development. Further validating these understandings, Gaitán-Hernández et al. [15] explored different LED light treatments on the growth and yield of *Pleurotus eryngii* in a greenhouse setting.

Their findings highlight the importance of longer light periods in enhancing biological efficiency and protein content in mushrooms, sustaining the crucial relationship between light duration and mushroom development. While the overall differences may not be statistically significant, these nuanced observations shed light on the intricate relationship between light duration and cap diameter in white oyster mushroom cultivation. Understanding these dynamics can permit cultivators to optimize their lighting strategies, ultimately enhancing the quality and yield of white oyster mushroom harvests.

3.5 Number of Fruiting Bodies Formed

The impact of varying white LED light durations on the number of fruiting bodies formed across multiple harvests reveals intriguing patterns that underscore the complex relationship between light exposure and mushroom development (see Table 1). Initially, during the first and second harvests, there were no significant differences among the treatments, suggesting that the initial phase of fruiting body formation may not be heavily influenced by light duration. This finding aligns with the understanding that early-stage mushroom development is primarily governed by factors other than light exposure, such as substrate quality and moisture content. According to Attaran-Dowom et al. [16], environmental factors like substrate composition and moisture levels play a crucial role in the early stages of mushroom development. Lavely [17] also emphasizes that factors such as temperature, humidity, and substrate quality are critical during the initial phases of mushroom growth.

However, as the harvesting cycles progressed, distinct trends began to emerge. During the third harvest, the treatment with 16 hours of light exposure resulted in a significantly higher number of fruiting bodies compared to other treatments. This suggests that extended light exposure may enhance the productivity of white oyster mushrooms during the later stages of growth. This observation is consistent with the findings of Halabura et al*.* [9] and Zhang et al*.* [13], who reported that prolonged LED light exposure could positively influence the formation and development of fruiting bodies in various mushroom species. In contrast, the treatment with 8 hours of light exposure consistently resulted in the lowest number of fruiting bodies across multiple harvests. This pattern suggests that shorter light durations may limit the overall yield potential of white oyster mushrooms, possibly due to insufficient light energy being provided for optimal physiological processes. This aligns with previous research that highlights the critical role of adequate light exposure in promoting the development of fruiting bodies [18].

Interestingly, while no significant differences were observed among treatments during the fourth harvest, the fifth harvest revealed highly significant results. The variability observed across harvests highlights the dynamic nature of mushroom growth and the complex interplay between environmental factors and physiological processes. This complexity is echoed in studies such as Wang et al. [18], which emphasize that mushroom growth responses to light conditions are not linear and can vary depending on the specific growth stage and environmental context.

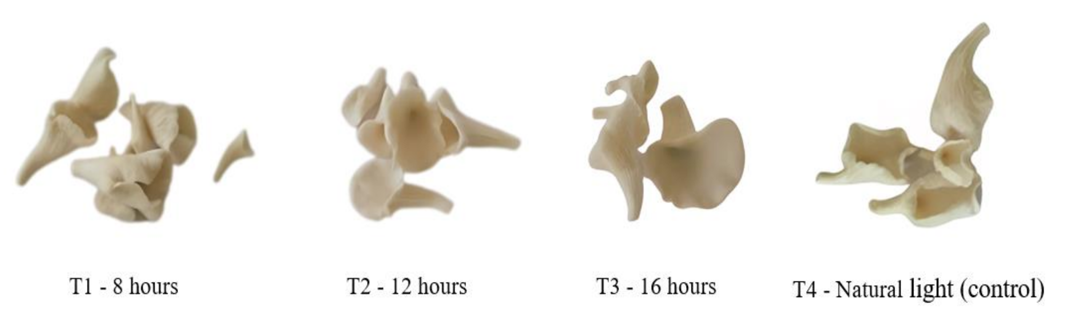

Fig. 3. Fruiting bodies of white oyster mushroom as affected with varying duration of light exposure using white light-emitting diode (LED)

T1 - 8 hours: Mushrooms are relatively small and closed; T2 - 12 hours: Mushrooms are slightly larger and more open; T3 - 16 hours: Mushrooms show further enlargement and opening; and T4 - Natural light (control): Mushrooms have a more irregular shape and size compared to the LED-exposed groups

Table 1. Yield performance of white oyster mushroom (*Pleurotus ostreatus* L.) under varying duration using white light-emitting diode (LED)

Treatment	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest
	Cap Diameter (cm)				
T_1: 8 hours lighting	5.50	6.27	5.50	5.77	5.53
T_2: 12 hours lighting	5.90	5.73	5.83	5.73	5.37
T_3: 16 hours lighting	5.93	6.37	6.00	5.87	5.90
T_4: Natural light (Control)	5.70	5.60	5.33	5.03	5.20
P-value	**0.5209^{ns}**	**0.2765^{ns}**	**0.1400^{ns}**	**0.1378^{ns}**	**0.1425^{ns}**
%, C.V.	**6.69**	**8.87**	**5.96**	**7.54**	**6.08**
	Number of Fruiting Bodies Formed				
T_1: 8 hours lighting	9.57	8.67	7.60^{b}	7.80	6.77^{c}
T_2: 12 hours lighting	10.43	9.47	8.40^{b}	7.33	6.43^{c}
T_3: 16 hours lighting	10.97	9.97	10.30^{a}	8.90	7.57^{b}
T_4: Natural light (Control)	11.23	10.67	8.07^{b}	9.37	9.43^{a}
P-value	**0.5760^{ns}**	**0.3771^{ns}**	**0.0451^{*}**	**0.0663^{ns}**	**0.001^{**}**
%, C.V.	**14.39**	**13.87**	**11.59**	**10.35**	**5.31**
	Fresh Weight (g) of Mushroom Fruiting Bodies				
T_1: 8 hours lighting	45.30	50.70	32.60	31.57	29.30^{bc}
T_2: 12 hours lighting	45.17	38.43	34.93	32.43	30.00^{b}
T_3: 16 hours lighting	44.97	43.37	44.40	36.73	34.00^{a}
T_4: Natural light (Control)	42.27	39.27	33.67	29.67	27.07^{c}
P-value	**0.4485^{ns}**	**0.2553^{ns}**	**0.2169^{ns}**	**0.0731^{ns}**	**0.0008^{**}**
%, C.V.	**5.69**	**17.64**	**11.78**	**8.59**	**4.06**

*Means with the same letter in a column are not significantly different at 5% level based on Least Significant Difference (LSD) Test. **-highly significant (P≤ 0.01), *-significant (P≤ 0.05), ^{ns}-not significant (P≥ 0.05)*

3.6 Fresh Weight (kg) of Mushroom Fruiting Bodies

The impact of varying white LED light duration resulted in a substantial improvement in the fresh weight of white oyster mushrooms (see Table 1). Among the treatments, 8 hours of light exposure obtained the highest average harvest during the first (45.30 g) and second harvests (50.70 g). In contrast, 16 hours and 12 hours of light exposure demonstrated the lowest average harvests of 42.27 g and 38.43 g, respectively, during the same harvesting period. However, 16 hours exhibited the highest average harvest during the third (44.40 g) and fourth (36.73 g) harvests. Interestingly, during these harvesting periods, a decrease in the average harvest was observed in 8 hours, comparable to the control (natural light).

Thus, the overall differences were not statistically significant from the first to the fourth harvest. Remarkably, in the fifth harvest, statistical analysis revealed highly significant results among the treatments. Similar to the fourth harvest, T3 (16 hours) obtained the highest average with a mean of 34.00 kg, followed by T2 (12 hours) and T1 (8 hours) with means of 30.00 kg and 29.30 kg, respectively. Once again, T4 (natural light) had the lowest fresh weight with a mean of 27.07 kg. These findings highlight the variable effects of different light durations on oyster mushroom yield across multiple harvests. The results corroborate other recent research demonstrating the intricate relationship between light exposure and the growth of mushrooms. The growth and maturation of the white oyster mushroom fruiting body, especially in the pileus (cap) area, are positively impacted by blue light, according to Wang et al. [18]. This affirms the enhanced yield observed in the current study when exposed to longer white LED light exposure, indicating that particular light durations and wavelengths are essential for mushroom culture optimization. Furthermore, it has been shown by and Zawadzka et al. [6] and Halabura et al. [9] that duration and quality of light are important for mushroom physiology, hence supporting the notion that specific light conditions might improve both yield and quality. These results offer important new information for the creation of more productive farming methods, especially in controlled settings with carefully controlled light.

4. CONCLUSION

In conclusion, the analysis of the data presented valuable understandings into the effects of different durations of white LED lighting on the growth and yield performance of white oyster mushrooms (*Pleurotus ostreatus* L.). Across various parameters such as mycelial growth, fruiting bodies formation, cap diameter, and yield, Treatment 2 (12 hours) consistently demonstrated superior performance compared to other treatments. This suggests that a moderate duration of 12 hours of light exposure may be optimal for promoting optimal growth and yield outcomes in white oyster mushroom cultivation. However, it is important to acknowledge that Treatment 3 (16 hours) also exhibited notable advantages in certain aspects, particularly in terms of cap diameter and fruiting bodies formation during specific harvests. Further research is needed to explore additional factors influencing productivity and to refine cultivation practices accordingly.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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