PLASTICISED MYCELIUM BLOCK USING BUTTON AND OYSTER MUSHROOM

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Abstract

This research explores the use of button and oyster mushrooms to create sustainable mycelial bricks from agricultural waste, specifically rice straw. By cultivating mushrooms on sterilized rice straw, mycelium forms a dense, interwoven network, which is then molded into eco-friendly bricks. The study aims to optimize the cultural characteristics of these mushrooms, enhance their growth on rice straw, and characterize the chemical, mechanical, and physical properties of the resulting bio-bricks. The findings suggest that mycelium-based bricks offer a viable, biodegradable alternative to traditional building materials, contributing to waste reduction and resource efficiency while addressing food security through mushroom cultivation.

1 Introduction

Mycelium-based bricks, an innovative biomaterial derived from the root structure of fungi, have emerged as a potential solution to address sustainability challenges in the construction industry. Mycelium, the vegetative part of mushrooms, forms an extensive network of fungal

ISBN:97881-19905-39-3

threads that naturally bind to agricultural waste. This unique ability to metabolize and bind organic materials has been harnessed to create mycelium bricks, offering a sustainable alternative to conventional construction materials like concrete and clay bricks. These mycelium bricks are not only environmentally friendly but also versatile, lightweight, and strong, making them a promising addition to the construction sector.

The production of mycelium bricks begins with the use of agricultural by-products such as straw, sawdust, or corn husks. These substrates are inoculated with mycelium spores, which then grow through and digest the organic matter, binding it into a dense, cohesive structure. The growth process is carefully controlled to ensure that the mycelium colonizes the substrate effectively, forming a material that can be molded into the desired shape and density. Once the mycelium has fully colonized the substrate, the bricks are dried to stop further fungal growth, resulting in a material that is both lightweight and strong. This process not only creates a building material but also contributes to waste reduction, as it repurposes agricultural waste into a high-value product [1].

One of the most significant advantages of mycelium bricks lies in their environmental sustainability. Traditional building materials such as concrete have large carbon footprints due to energy-intensive production processes and the extraction of raw materials. In contrast, mycelium bricks are grown using minimal energy, relying on agricultural waste as a substrate, which helps reduce carbon emissions and resource consumption. Furthermore, mycelium bricks are fully biodegradable, ensuring that they return to the earth without leaving any harmful residues at the end of their lifecycle. This feature makes them ideal for promoting a circular economy, where waste is minimized, and resources are efficiently used [2].

The physical properties of mycelium bricks are also noteworthy. Despite their lightweight nature, they possess considerable strength and durability, making them suitable for various construction applications. These bricks have excellent thermal and acoustic insulation properties, which enhance energy efficiency and comfort within buildings. Moreover, mycelium bricks can be molded into different shapes and sizes, offering architects and

ISBN:97881-19905-39-3

designers a great deal of flexibility in creating aesthetically pleasing and functional structures. This versatility allows mycelium bricks to be used not only in construction but also in other industries, such as furniture, packaging, and even fashion [1].

The use of mycelium-based materials extends beyond sustainable construction. Researchers have explored their applications in furniture design, packaging, and disaster relief. In emergency situations, mycelium bricks' lightweight nature allows for easy transportation and rapid deployment. Their insulating properties improve the comfort of temporary shelters, making them a viable option for disaster relief efforts. Additionally, the potential for these materials to be tailored to specific needs, including flexible densities and mechanical properties, provides opportunities for further innovation across different sectors [3], [4].

Mycelium-based composites have been a subject of increasing interest due to their environmental sustainability and adaptability. Previous research detailed the bioconversion processes that transform lignocellulosic biomass into valuable products. They emphasized that optimizing bioconversion techniques, such as pretreatment, hydrolysis, and fermentation, could enhance the efficiency of biomass processing. Furthermore, microbial and enzymatic systems play a crucial role in breaking down complex lignocellulosic structures, which can be further utilized to produce biofuels, biochemicals, and other value-added products [3].

While working on, the mechanical, physical, and chemical properties of mycelium-based composites were analyzed, the researchers found that the type of substrate significantly influences the final properties of the composites. Substrates rich in lignin produced stronger mycelium-based materials, showcasing the importance of substrate selection in optimizing the material's performance. This study concluded that the development of mycelium composites requires careful consideration of substrate composition to meet specific application needs [6].

Earlier research work focused on the production of mycoblocks using Pleurotus ostreatus for sustainable construction. Their research demonstrated that these mycoblocks had good compressive strength and durability, making them suitable for non-load-bearing applications.

ISBN:97881-19905-39-3

Moreover, the environmental benefits of using agricultural waste as a substrate were emphasized, positioning mycelium-based bricks as a promising alternative to conventional materials in sustainable construction [7].

Earlier work investigated the fabrication of advanced materials derived from fungal mycelium. By manipulating growth conditions, they successfully tailored the physical properties of mycelium-based materials, such as density, flexibility, and mechanical strength. This adaptability highlights the potential of mycelium to replace traditional materials, including plastics and composites, with more sustainable alternatives [8].

The primary objectives of this project are to optimize the cultural characteristics of Button mushroom (Agaricus bisporus) and Oyster mushroom (Pleurotus ostreatus), to optimize the growth of Button and Oyster mushrooms on rice straw to produce bio-bricks, and to characterize the chemical, mechanical, and physical properties of the resulting composite materials. These objectives aim to improve the efficiency of mycelium growth on rice straw, as well as enhance the material properties of the resulting bio-bricks, paving the way for their use as a sustainable alternative in construction and other industries.

2 Experimental Procedure

2.1 Optimize Cultural Characteristics of Button Mushroom and Oyster Mushroom

Optimizing the cultural characteristics of Agaricus bisporus (Button mushroom) and Pleurotus ostreatus (Oyster mushroom) is fundamental for maximizing their yield and quality. This section provides the detailed materials and methods used to optimize the growth and morphological characteristics of these mushrooms.

2.1.1 Materials

The fungal strains used in this study were sourced from reputable suppliers and culture collections. Agaricus bisporus was obtained from a certified culture collection, while Pleurotus ostreatus was sourced from a reliable mycological supplier. To prepare the media, Potato Dextrose Agar (PDA) and Rice Straw Agar (RSA) were selected for their ability to support fungal growth and provide necessary nutrients. Chemicals such as Potato Dextrose, Agar, Deionized Water, and Ethanol (70%) for sterilization were used, as well as gypsum ($CaSO_4$) and calcium carbonate ($CaCO_3$) to enhance the media's structural properties. The following equipment was utilized: Laminar Flow Hood, Autoclave, Incubators set to different temperatures, pH Meter, Sterile Petri Dishes, Glassware, Analytical Balance, and a Microscope.

2.1.2 Methodology

To prepare the Potato Dextrose Agar (PDA) media, 200g of potatoes were boiled, filtered to obtain a potato infusion, then 20g of dextrose and 15g of agar were added. The mixture was autoclaved at 121°C for 20 minutes to sterilize and solidify the medium (Meyer et al., 2013). For the Rice Straw Agar (RSA), rice straw was processed similarly with an appropriate amount of agar and dextrose added, following standard protocols [9].

For inoculation, the media was poured into sterile Petri dishes under a laminar flow hood to prevent contamination. A small piece of actively growing mycelium of both A. bisporus and P. ostreatus was transferred to the center of each plate using a sterile scalpel [10]. The inoculated plates were incubated at varying temperatures (20°C, 25°C, and 30°C) to identify the optimal growth temperature for both species. Each condition was replicated five times to ensure statistical reliability.

Growth was monitored by measuring the radial growth of mycelium every 24 hours until complete colonization of the Petri dish was achieved. The growth rate was calculated by measuring the diameter of the mycelial growth [11]. Morphological features were observed

ISBN:97881-19905-39-3

under a microscope to assess the hyphal characteristics such as diameter, branching, and density, which are key indicators of fungal health and growth [12].

For pH optimization, media with varying pH levels (5, 6, 7, and 8) were prepared by adjusting the pH with hydrochloric acid (HCl) or sodium hydroxide (NaOH) (Chand et al., 2018). These media were inoculated with A. bisporus and P. ostreatus as described above and incubated under the same conditions. The optimal pH was determined by comparing the growth rates and mycelial morphology across the different pH levels.

Data on growth rates and morphological observations were analyzed using one-way ANOVA to determine significant differences between temperature, media, and pH conditions [14]. The optimal growth conditions were identified based on the highest growth rate and best mycelial characteristics.

2.2 Optimize Growth of Button and Oyster Mushroom in Rice Straw to Produce Bio Bricks

The aim of this section is to optimize the growth of Agaricus bisporus and Pleurotus ostreatus in rice straw substrate to produce biobricks. The optimization of substrate preparation, inoculation techniques, and environmental conditions is key to obtaining robust mycelial growth and complete substrate colonization, which are essential for producing high-quality biobricks.

2.2.1 Materials

The fungal strains used for substrate colonization were Agaricus bisporus and Pleurotus ostreatus, both sourced from established culture collections. The substrate materials consisted of rice straw, which was collected from local agricultural fields. To supplement the rice straw and provide additional nutrients, wheat bran, gypsum ($CaSO_4$), and calcium carbonate ($CaCO_3$) were used. Ethanol (70%) was used for sterilization, and the required equipment included Laminar Flow Hood, Autoclave, Incubators with controlled temperature

ISBN:97881-19905-39-3

and humidity, Sterile Petri Dishes, Glassware (flasks, beakers), Analytical Balance, Moisture Analyzer, Molds for biobrick formation, and a Drying Oven.

2.2.2 Methodology

Rice straw was prepared by chopping it into small pieces (2-3 cm) and drying it to a moisture content of 10-12%, ensuring that it was suitable for fungal colonization [14]. The dried rice straw was then sterilized in an autoclave at 121°C for 20 minutes to eliminate any potential contaminants [9]. After sterilization, the straw was supplemented with 10% wheat bran, 2% gypsum, and 1% calcium carbonate to enhance the nutritional content and structural integrity of the substrate [15].

Grain spawn for both A. bisporus and P. ostreatus was prepared by inoculating sterilized cereal grains with the respective mycelium and incubating until the grains were fully colonized [16]. The supplemented rice straw substrate was inoculated with 10% (w/w) of the prepared grain spawn. The inoculation was done under sterile conditions, ensuring even distribution of the mycelium throughout the substrate.

The inoculated substrates were then incubated in controlled environments with varying temperatures (20°C, 25°C, and 30°C) and relative humidity levels between 80-90%. Proper aeration was maintained throughout the incubation period to avoid CO_2 accumulation, which can inhibit mycelial growth [9]. The substrate was incubated for 2-4 weeks, until full colonization of the rice straw by the mycelium was achieved.

Once the substrate was fully colonized, it was placed into pre-sterilized molds to form biobricks. The substrate was compacted within the molds to ensure firmness [17]. The molded biobricks were incubated for an additional week to allow the mycelium to further knit the substrate into a cohesive structure. After this incubation period, the biobricks were dried in a drying oven at 60°C until they reached a moisture content of less than 10% [15]. Subsequently, the dried biobrick is dipped in 1% starch solution, and mixed with glycerol at 1: 4 ratio and heated at 850C for 16 hours.

ISBN:97881-19905-39-3

Characterization of Biobricks: The physical properties of the biobricks, including density, compressive strength, and water absorption, were measured using standard methods. The biodegradability of the biobricks was assessed by burying the samples in soil and monitoring their decomposition over time [18].

Data Analysis: Data on the physical properties and biodegradability of the biobricks were analyzed using one-way ANOVA to determine the optimal conditions for substrate preparation and incubation [19]. The optimal combination of substrate supplementation, inoculation rate, and incubation conditions was identified based on the quality of the biobricks produced.

3 Results and Discussions

3.1 Optimization of Growth Conditions for Button and Oyster Mushrooms

Button Mushroom Optimization: The growth of Agaricus bisporus (Button mushroom) was optimized at various temperatures and pH levels. The most favorable conditions were 25°C and pH 6, where the mycelial diameter reached 92 mm after 25 days, with a daily growth rate of 3.68 mm (Fig 5.1). This growth rate was substantially better than that observed at lower (10°C) and higher (40°C) temperatures, where growth was significantly slower. The results align with previous studies suggesting optimal growth for Button mushrooms at 20-25°C and pH 6-7. Lower temperatures (e.g., 10°C) hindered mycelial growth due to reduced metabolic activity, and more acidic pH (e.g., pH 4) further limited growth. These findings highlight the importance of maintaining specific temperature and pH conditions for optimal cultivation.

(a) (b)

Fig. 5.1 Characteristic growth of mushroom in fungal medium at pH 6 (a) and pH8 (b)

Oyster Mushroom Optimization: Pleurotus ostreatus (Oyster mushroom) exhibited

ISBN:97881-19905-39-3

Figure 1:

Table 1: Growth rate of Button Mushroom in fungal medium

Sl. No.	Temperature (°C)	pH	Growth, Diameter of mycelium for 25 days, mm	Growth rate, Diameter of mycelium for 1 day, mm
1	10	6	18	0.72
2	10	8	34	1.36
3	25	8	56	2.24
4	25	6	90	3.6
5	40	6	65	2.6
6	40	8	69	2.76
7	25	4	25	1
8	40	4	19	0.76
9	10	4	12	0.48
10	25	6	92	3.68

ISBN:97881-19905-39-3

Figure 2:

optimal growth at 25°C and pH 6, with a mycelial diameter of 123 mm after 25 days, yielding a growth rate of 4.92 mm/day(Table 5.2). The growth rate was slower at 40°C and pH 4, indicating that extreme conditions hindered development. As with Button mushrooms, Oyster mushrooms showed better growth at moderate temperatures (25°C) and neutral pH levels, confirming their similar growth requirements. The results are consistent with existing literature, which suggests that Oyster mushrooms thrive within the temperature range of 20-30°C and pH 5.5-6.5.

ISBN:97881-19905-39-3

Table 2: Growth rate of Oyster Mushroom in fungal medium

Sl. No.	Temperature (˚C)	pH	Growth, Diameter of mycelium for 25 days, mm	Growth rate, Diameter of mycelium for 1 day, mm
1	10	6	23	0.92
2	10	8	34	1.36
3	25	8	66	2.64
4	25	6	123	4.92
5	40	6	67	2.68
6	40	8	76	3.04
7	25	4	34	1.36
8	40	4	23	0.92
9	10	4	34	1.36
10	25	6	112	4.48

3.2 Optimization of Growth in Rice Straw for Bio-Brick Production

Button Mushroom in Rice Straw: Button mushrooms were successfully cultivated in rice straw under controlled conditions (25˚C, pH 6). Over 24 days, the mycelial diameter increased progressively, reaching 156 mm, with a peak growth rate of 6.50 mm/day. The growth pattern was typical, with initial slow growth followed by rapid colonization. This suggests that the mycelium initially adapts to the rice straw substrate before entering a phase of accelerated growth. The use of rice straw as a substrate not only supports sustainable mushroom cultivation but also offers an effective way to utilize agricultural waste, reducing costs and promoting environmental sustainability [20].

Oyster Mushroom in Rice Straw: Oyster mushrooms also demonstrated effective growth in rice straw, with the mycelial diameter reaching 198 mm after 24 days, achieving a growth rate of 8.25 mm/day. The growth pattern followed a similar trend to that of Button mushrooms, with an initial slower growth phase followed by rapid colonization. This faster growth rate in comparison to Button mushrooms suggests that Oyster mushrooms are more aggressive in colonizing lignocellulosic substrates like rice straw. The ability of Oyster mushrooms to thrive on rice straw further supports their potential in bio-based material production, including bio-bricks, aligning with their suitability for bioconversion processes

ISBN:97881-19905-39-3

(Fig 5.2).

Figure 3:

3.3 Characterization of Composite Properties

Dry Density and Moisture Content: The dry density of the composite was measured following ISO standards, while moisture content was calculated using the formula from ISO 16979:2003.

ISBN:97881-19905-39-3

Figure 4:

The results indicated that the composite's moisture content decreased as the rice straw was colonized by the mushrooms, reflecting the absorption of water by the mycelium during growth.

Mechanical Testing in Compression: Compressive stiffness was evaluated using ASTM D3501 standards on an Instron 5900R load bench. The stress-strain curves indicated that

ISBN:97881-19905-39-3

the mycelium-enriched rice straw composites demonstrated significant mechanical properties, with a noticeable increase in stiffness and structural integrity as the incubation time progressed. The results confirmed that the mycelium's growth reinforced the rice straw, enhancing its potential for use in bio-brick production.

Rate of Water Absorption: The rate of water absorption was measured to evaluate the composite's ability to absorb moisture under different conditions. The results showed that the mycelium-colonized rice straw exhibited enhanced water absorption properties, which is a key factor for bio-based materials used in construction, particularly for applications like bio-bricks where moisture resistance is crucial.

4 Conclusion

This study demonstrated that both Button and Oyster mushrooms can be optimized for growth in fungal media and rice straw, with optimal growth conditions of 25°C and pH 6 for both species. The use of rice straw as a substrate proved to be effective for mycelial colonization and offers a sustainable alternative for mushroom cultivation. Furthermore, the mechanical and physical properties of the mycelium-enriched rice straw composites show promising results for applications in bio-brick production. These findings contribute to the development of environmentally friendly and cost-effective bio-based materials, aligning with broader sustainability goals in agriculture and construction.

ISBN:97881-19905-39-3