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MycoWrap: Using Mycelium-Grown Coconut Husk Fibers and Sawdust as an Alternative to Traditional Polystyrene Foam

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Abstract—*Polystyrene foam is widely used in packaging and construction but poses environmental challenges due to its persistence and chemical leaching. This study investigates mycelium-based composites incorporating coconut husk fibers and sawdust as sustainable alternatives. Three treatments were tested, each varying in material composition. Treatment 3 demonstrated the most favorable mechanical properties overall, particularly in flexural and tensile strength, while Treatment 1 showed the highest biodegradability. All treatments exhibited higher water absorption than polystyrene and less uniform thickness. Statistical analysis confirmed significant differences among treatments in all tested properties. The results indicate that mycelium-based composites have strong potential as eco-friendly alternatives to polystyrene foam, though improvements in durability and water resistance are necessary. Further research should focus on material optimization, production scaling, and long-term environmental impact.*

Keywords— *Agricultural waste utilization; Bio-based material; Biodegradable packaging; Coconut husk fiber; Eco-friendly insulation; Mycelium-based foam; Mycelium composite; Polystyrene alternative; Sawdust; Sustainable material.*

I. INTRODUCTION

Polystyrene Foam Is Widely Used in the Plastic Industry, Commonly Known by the Brand Name "Styrofoam." It Is a Synthetic Polymer Made from Styrene, a Petroleum-Derived Compound and a Non-Renewable Resource. For decades, products made from polystyrene foam have been utilized in food service, packaging, construction, and arts—primarily for single-use applications. This extensive use has resulted in substantial environmental accumulation. According to the article *No More Styrofoam* (2018), approximately 2.3 billion kilograms of polystyrene foam are discarded annually into landfills and waterways, with this amount projected to increase.

While polystyrene foam is valued for its practicality and affordability, it presents serious environmental and public health challenges. Styrene, the base chemical, is a suspected human carcinogen. Once discarded, the foam breaks into smaller particles, which are often ingested by marine animals, birds, and other wildlife. This not only causes malnutrition or internal blockages but also introduces toxins into the food chain. Studies such as World Centric (2019) highlight the leaching of hazardous chemicals from polystyrene when exposed to aquatic environments.

Another significant concern is its non-biodegradable nature. Lewis's (2019) study discovered that polystyrene foam may remain in landfills forever, increasing the worldwide waste problem and incurring expensive cleanup expenses. Although technically recyclable, contamination from food waste and additives often renders recycling economically unviable and impractical. As a result, the majority of discarded foam ends up in landfills.

In the Philippines, an archipelagic nation with extensive coastlines, the impacts of polystyrene pollution are especially severe. The widespread use of Styrofoam in food services, retail, and exports contributes to increasing plastic waste. The National Ecological Solid Waste Management Act (Republic Act No. 9003), which the Philippine government passed in 2001, aims to solve this problem (Philippine Congress, 2001). However, despite this legislation, enforcement and effectiveness vary across regions, and Styrofoam remains prevalent in waste streams (Guerrero et al., 2013).

This issue is evident in Zamboanga City, a highly populated urban area in the southern Philippines. As of the 2020 census, the population stands at approximately 977,081 (PSA, 2020), making it one of the most densely populated cities in the country. The city continues to experience widespread use of polystyrene foam, particularly in commercial and food industries. Local initiatives, such as waste segregation programs, aim to reduce environmental impacts, but balancing industrial demands with sustainability remains a challenge (Zamboanga City Environmental Management Office, 2022).

To address this, it is essential to explore eco-friendly alternatives to polystyrene foam. One promising solution is the use of Reishi mushrooms to grow mycelium on coconut husk fibers and sawdust—both abundant byproducts in Zamboanga's rural communities. Coconut husks are commonly discarded after copra production, while sawdust is generated in local lumberyards. Developing mycelium-based materials using these resources offers a sustainable, biodegradable alternative that can also support local economies.

Although mycelium composites have been explored in previous studies, limited research has focused on the use of Reishi mushrooms in combination with coconut husk fibers and sawdust. The potential for this combination to enhance mechanical and environmental performance remains underexplored. Additionally, existing studies often lack standardized testing methods and fail to address the scalability of production.

This study, titled "MycoWrap: Using Mycelium-Grown Coconut Husk Fibers and Sawdust as an Alternative to Traditional Polystyrene Foam," seeks to address these gaps by evaluating substrate formulation, mechanical strength, water absorption, biodegradability, and potential for local implementation. The findings aim to contribute to the development of sustainable materials that could replace polystyrene foam in various applications.

II. METHODOLOGY

2.1 Secondary Data Gathering

This study utilized secondary data from research papers accessed through local libraries and online sources to understand mycelium's development and use in agricultural waste. It focused on the potential of mycelium-grown coconut husk fiber and sawdust as sustainable alternatives to low-density polystyrene foam.

2.2 Research Locale

The experiment was conducted at the researcher's residence in Malagutay, Zamboanga City, allowing close monitoring and control of variables. This familiar setting ensured data accuracy and enabled quick adjustments to unexpected challenges.

2.3 Collection and Preparation of Raw Materials

The preparation of the treatment group using coconut husk fibers and sawdust was conducted through a carefully staged process to ensure the uniformity and quality of the substrate blend necessary for mycelial colonization. The procedure commenced with the collection of mature coconut husks, which are typically discarded after coconut harvesting. These husks underwent a retting process, wherein they were submerged in water to soften the fibrous material and promote microbial action that facilitates fiber separation.

After an adequate retting period, the husks were removed from the water and partially sun-dried to reduce excess moisture. This partial drying step allowed for easier manual extraction of the coir, during which the fibrous layer was separated from the woody outer layer. The extracted fibers were then inspected and sorted to remove overly coarse or non-uniform particles.

The sorted coconut husk fibers were then mixed with sawdust to form the primary substrate base. The ratio of the components was prepared in accordance with predefined treatment formulations. This mixture was subsequently subjected to mechanical shredding using a food processor or similar equipment to further refine the material. This shredding process was crucial for reducing the particle size and breaking down fibrous strands to create a homogeneous and finely textured blend. The removal of long, coarse fibers or hairy strands was essential to achieve consistent texture and enhance the suitability of the substrate for mycelial infiltration.

Once the mixture attained the desired particle consistency, it was thoroughly soaked in water. This hydration phase served to improve the substrate's moisture content, which is a critical factor in promoting fungal colonization and nutrient absorption. The fully hydrated mixture was then temporarily stored in clean, covered containers in preparation for the sterilization process, which would eliminate potential contaminants prior to fungal inoculation.

2.4 Mechanical Properties

2.4.1 Compressive Strength Test

The compressive strength of the mycelium-grown composite material was evaluated using an improvised manual testing setup. This assessment aimed to determine the material's ability to resist compressive forces and its suitability as an alternative to low-density polystyrene foam.

Specimens were prepared in uniform square shapes with dimensions guided by a modified version of the ASTM D1621 standard. Before testing, each sample's initial weight and dimensions were recorded to ensure consistency and accurate analysis.

During the test, a steadily increasing compressive load was applied vertically to the samples until deformation or failure was observed. The equipment used measured both the applied force and the corresponding displacement of the material, generating a stress–strain response curve. This curve was used to evaluate the compressive strength, stiffness, and energy absorption capacity of the material.

Compressive Strength = Maximum Load / Cross-sectional Area (1)

2.4.2 Flexural Strength Test

Flexural strength testing was conducted using an improvised manual setup configured as a three-point bending apparatus. This test was designed to evaluate the bending resistance of the mycelium-grown composite material and its potential to perform comparably to conventional foams.

Specimens were prepared in accordance with the dimensional guidelines of a modified ASTM D790 standard. Each sample was placed horizontally on two supports, and a concentrated load was applied at the midpoint of the span. The loading rate was adjusted in proportion to the depth of the specimen to ensure accurate and consistent stress distribution, as specified by the standard procedure.

The setup allowed for the observation of deformation behavior as the load increased until failure or visible bending occurred. Flexural strength was calculated based on the maximum load sustained by the specimen at the midpoint.

$$\sigma_f = \frac{3FL}{2bd^2} \tag{2}$$

2.4.3 Tensile Strength Test

Tensile strength was evaluated using an improvised manual testing setup, adapted in accordance with the general guidelines of the ASTM D638 standard. This test aimed to assess the material's resistance to pulling forces and its behavior under uniaxial tension.

Uniform specimens were prepared in a rectangular shape, cut according to the prescribed standard dimensions. Prior to testing, all samples were conditioned in a controlled

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environment to stabilize their physical properties. This step ensured uniformity in moisture content and temperature across all test pieces.

Each specimen was securely mounted into a manually operated tensile fixture, with careful alignment to prevent bending or torsional stresses during the procedure. A gradually increasing tensile load was applied by adding weights until the sample experienced failure. Throughout the process, the applied force and the resulting deformation were monitored to determine the material's tensile performance.

$$TS = F / A \tag{3}$$

2.5 *Physical Properties*

2.5.1 Hardness Test

The hardness of the mycelium-based composite material was assessed in accordance with the PNS ASTM D2240 standard. This test aimed to evaluate the material's resistance to surface indentation, providing an indication of its durability and surface integrity.

Specimens were prepared with consistent dimensions and conditioned in a controlled environment prior to testing to ensure reliable and repeatable results. A durometer was used to perform the hardness measurements. The device was applied perpendicularly to the sample surface, and the depth of indentation was recorded as the hardness value.

Multiple points on each specimen were tested to capture variations across the surface and to generate a representative hardness profile. Testing conditions were kept constant throughout all measurements to minimize external variability.

The resulting data offered insights into the material's mechanical resilience and its potential to perform under compressive or impact-related stress in real-world applications.

2.5.2 Thickness Test

The thickness of the mycelium-grown composite material was measured following a modified version of the ASTM D1980 standard. The purpose of this experiment was to determine the uniformity and dimensional consistency of the manufactured specimens.

Each specimen was placed on a level surface to ensure accurate readings. A digital caliper was used to obtain precise measurements of thickness. For each sample, measurements were taken at multiple points across the surface to account for potential variations. The values were then averaged to determine the representative thickness of the specimen.

This procedure helped evaluate the production consistency of the material and provided important data for comparing dimensional stability across treatment groups.

2.5.3 Water Absorption Test

The water absorption test on the material was conducted following the ASTM C578 standard. Replicates were prepared for each treatment ratio. The material was molded into a uniform thickness. The dry weight of each sample was recorded before soaking in distilled water. The samples were fully submerged for a set period. After immersion, the samples were removed and gently dried with a clean cloth, avoiding excessive pressure. The wet weight of each sample was then recorded.

$$\text{Water Absorption (\%)} = [(\text{Wet Weight} - \text{Dry Weight}) / (\text{Dry Weight})] \times 100 \tag{4}$$

2.6 *Biodegradability Test*

2.6.1 Decomposition Rate

To determine the biodegradation rate of mycelium-grown coconut husk fibers and sawdust samples, the ASTM D5511 standard was followed. Replicates were prepared for each treatment ratio. Each sample was molded to match the thickness of the final product design. Initially, the mass of each sample was recorded. The samples were then stabilized in a controlled environment before the test began. They were buried at a specified depth in soil, and a temperature monitor was used to track the room temperature, which was checked at regular intervals throughout the day. The soil was carefully removed after varying time periods, and the samples were taken out of the ground. The samples were then weighed once more to measure mass loss and determine the rate of biodegradation.

$$\textit{Biodegradation Rate}\ (\%) = \left(\frac{\textit{Initial Mass} - \textit{Final Mass}}{\textit{Initial Mass}}\right) \times 100 \tag{5}$$

III. Result and Discussion

The results were discussed in detail, aligning each key finding with the specific research objectives to ensure clarity and relevance. Particular focus was given to evaluating the performance of the different treatment groups in comparison to the control, highlighting any significant trends, differences, or patterns observed during the analysis. The discussion also considered the broader implications of the findings—both in terms of practical application and their contribution to the existing body of knowledge. These insights served as a critical basis for formulating well-grounded conclusions and actionable recommendations, which are addressed in the succeeding chapter. Through this structured presentation and interpretation of data, the chapter effectively connected the experimental results to the overarching goals of the study, transforming raw data into meaningful information.Equations Style.

The summary of results for the Mechanical and Physical Properties of the mycelium-grown coconut husk fibers and sawdust, alongside the traditional polystyrene foam, was evaluated against the prescribed standards set by the American Society for Testing and Materials (ASTM). Specifically, the analysis considered Compressive Strength in accordance with ASTM D1621, Flexural Strength under ASTM D790, Tensile Strength as outlined in ASTM D638, and Water Absorption following ASTM C578. The mycelium-based samples demonstrated varying levels of performance across these properties depending on the treatment ratios. While some treatments approached or met the acceptable ranges, others fell below the standard thresholds. The traditional polystyrene foam served as a benchmark, consistently aligning with or exceeding the ASTM standards. These findings provide insight into the mechanical viability and water resistance of the bio-based alternatives compared to conventional synthetic foam materials.

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TABLE 1. Mechanical and Physical Properties Comparison to Low-Density Polystyrene Foam Standards

Properties	T1	T2	T3	T0
Compressive Strength (MPa)	0.001742	0.002118	0.002376	0.00274
Flexural Strength (MPa)	0.1848	0.2509	0.3102	0.1368
Tensile Strength (MPa)	0.0232	0.02843	0.03603	0.01943
Water Absorption (%)	53.9	30.77	30.51	1.353

The Mechanical, Physical, and Biodegradability properties of Treatment 1, Treatment 2, Treatment 3, and Treatment 0 (Control Group) were evaluated using a satisfaction-based performance scoring system.

Prescribed Values / Standard	Remarks
ASTM D1621	Passed
ASTM D790	Passed
ASTM D638	Passed
ASTM C578	Passed

Instead of ranking the treatments against one another, this system assigns numerical scores based on how well each property meets established standards. A 4-point scale was used: a score of 4 indicates highly satisfactory performance that exceeds the standard; 3 signifies satisfactory performance within the acceptable range; 2 reflects moderately satisfactory performance that falls below the standard but remains functional; and 1 denotes unsatisfactory performance that is significantly below the standard.

TABLE 2. Scoring of Mechanical, Physical, and Biodegradability Properties

Properties	Test	T1	T2	T3	T0
Mechanical	Compressive Strength (MPa)	1	1	3	4
	Flexural Strength (MPa)	1	3	4	2
	Tensile Strength (MPa)	3	3	4	2
Physical	Hardness Test	1	2	3	4
	Thickness Test	2	2	3	4
	Water Absorption (%)	1	1	2	4
Biodegradability	Decomposition Rate (%)	4	3	3	1
	Total Score:	**13**	**15**	**22**	**21**

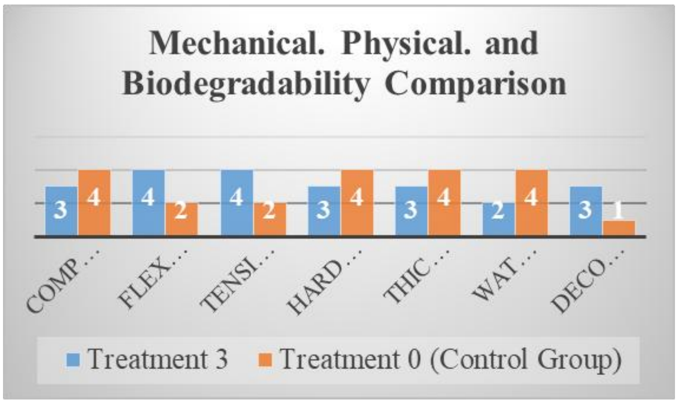

Figure 1. Mechanical, Physical, and Biodegradability Comparison of T1 and T0

In terms of mechanical properties, Treatment 3 demonstrated the strongest performance. For physical properties, the Control Group (Treatment 0) showed the highest performance overall. In terms of biodegradability, Treatment 1 exhibited the most effective breakdown over time. These outcomes reflect how each treatment's unique material composition influences its behavior, emphasizing the importance of selecting the right materials to achieve specific performance goals.

IV. Conclusion

The study explored the potential of mycelium-grown coconut husk fibers and sawdust as sustainable alternatives to traditional polystyrene foam by evaluating their mechanical properties, physical properties, and biodegradability.

In terms of mechanical properties, Treatment 0 (the control group using polystyrene foam) exhibited the highest compressive strength, demonstrating superior load-bearing capacity. Among the mycelium-based treatments, Treatment 3 showed the best compressive performance but still fell short of the control. For flexural strength, however, the mycelium-based Treatment 3 outperformed the control group, indicating better resistance to bending stresses. Similarly, in tensile strength, Treatment 3 also surpassed the control, showing better performance under stretching or pulling forces. All these differences in mechanical properties were statistically significant.

For the physical properties, Treatment 0 had the lowest hardness value, indicating less resistance to indentation, while Treatment 3 showed a substantially higher hardness, suggesting improved durability. In terms of thickness, the control group maintained the most consistent and stable dimensions. Although Treatment 3 was slightly below in thickness uniformity, it remained close to the desired standard. Regarding water absorption, the control group demonstrated excellent resistance with minimal absorption, while Treatment 3 exhibited significantly higher water uptake, highlighting a key area for improvement in moisture resistance. The variations in all physical property metrics were statistically significant.

With regard to biodegradability, Treatment 0 showed no notable degradation, retaining its weight throughout the testing period—underscoring its persistent nature in the environment. In contrast, Treatment 1 displayed the highest biodegradability among the mycelium-based samples, followed by moderate degradation observed in Treatment 3. This confirms the environmental advantage of mycelium-based materials over polystyrene foam, especially in terms of decomposition and sustainability.

When comparing the overall performance of mycelium-based materials to polystyrene foam, Treatment 0 excelled in compressive strength, dimensional stability, and water resistance, making it suitable for applications requiring durability and uniformity. However, mycelium-based Treatment 3 demonstrated better tensile and flexural strength, higher hardness, and significantly superior biodegradability, offering a more environmentally friendly alternative. While mycelium-based composites show promise, further development is necessary to enhance specific performance aspects and fully compete with the comprehensive functionality of polystyrene foam.

APPENDICES

Figure 2. *Soaked, Unbeaten Coconut Husk*

Figure 3. Collected Sawdust

Figure 4. Pre-developed Mycelium in each Treatment with Difference in Growth Rate After 7 Days

Figure 4. Pre-developed substrates are transferred to molds with minimal holes to allow airflow.

Figure 5. Oven-Drying the fully Colonized Treatments

Figure 6. Treatment 1 Samples

Figure 7. Treatment 2 Samples

Figure 8. Treatment 3 Samples

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