ISBN: 978-628-96613-1-6. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2025.1.1.2426

Analysis of the physical-mechanical properties of mycelium as a sustainable material in social housing

Double-blind peer review of authors is not guaranteed if authors are listed.
After acceptance, you upload the final version with authors and their affiliations

Abstract– ***The housing crisis in Ecuador has caused users to currently look for options that are more convenient for their economy and that generate climatic and ergonomic comfort, which in the last year 2025 has become an impossible task to achieve for people with minimal resources. In response to this challenge, this scientific document proposes the implementation of mycelium as a biomaterial for the design and development of social housing. This innovative approach seeks to address the problem of housing deficit and access to housing using sustainable and low-cost materials, which not only contribute to the improvement of living conditions but also promote environmentally friendly construction practices. The objective of this article is to analyze the productive conditions of the mycelium through its development phases for its use as a biomaterial in social housing in Ecuador, thus promoting the circular economy. In conclusion, the properties of mycelium are analyzed, characterized by being an adaptive, resistant material capable of being used in serious productions with a low environmental impact and an ability to rejoin the biological cycle after use.***

Keywords-- mycelium, ecological material, circular economy, flexible architecture.

I. Introduction

Global population growth, accompanied by accelerated urbanization, poses significant challenges to ensuring access to affordable and sustainable housing. This panorama is even more complicated in regions with a hot and humid climate, where environmental conditions aggravate the needs for thermal comfort and durability of construction materials. Furthermore, the construction industry has historically been one of the main responsible for the exploitation of natural resources and the generation of carbon emissions. Therefore, the search for constructive alternatives that balance economic, environmental and social aspects is more urgent than ever.

In this framework, the circular economy has emerged as a crucial strategy. This approach seeks to reduce waste and extend the useful life cycle of products by recycling, reusing and taking advantage of resources that would traditionally be discarded [1]. Within this perspective, the use of mycelium – the vegetative structure of fungi – is positioned as an innovative and sustainable option. Its ability to colonize organic substrates such as straw, sawdust and other agricultural waste allows these wastes to be transformed into solid and functional panels, suitable for various construction applications.

The mycelium stands out not only for its physical and thermal characteristics, but also for its low environmental impact. By consolidating into lightweight, insulating panels, it can replace conventional materials that require highly polluting processes, such as cement or petroleum-derived polymers. Furthermore, its ability to biodegrade and reintegrate into the environment at the end of its useful life makes it a clear example of a regenerative material within the natural cycle.

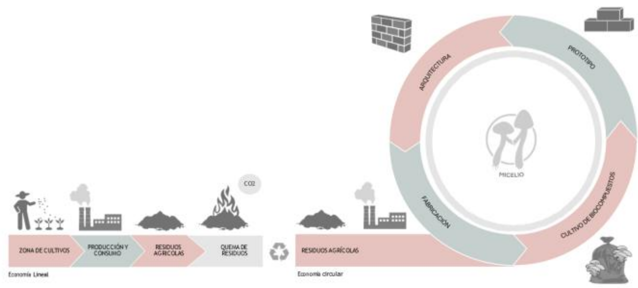

Fig. 1 Economía Circular – Mycelio
Note. An economic contribution of mycelium in constructionr (Salas, 2023).

Mycelium, the filamentous branched structure of fungi, has become a biomaterial of increasing interest for use in the construction of sustainable homes. Its high versatility, mechanical properties and biodegradation capacity position it as a strategic resource within the circular economy. This article presents research focused on the production of mycelium panels for their application in the construction of social housing, evaluating their mechanical resistance, thermal behavior and economic viability. Through laboratory tests, the ability of the mycelium to form rigid and resistant structures was determined, while its potential to reduce the carbon footprint and dependence on traditional materials with high emissions was analyzed. The results indicate that mycelium can offer thermal insulation properties and durability acceptable for use in low-cost residential environments, while also being a renewable, compostable material with reduced environmental impact [2]. This research seeks to contribute to the scientific literature on biomaterials and promote a paradigm shift in the construction of social housing, emphasizing the importance of the circular economy and sustainable innovation.

This article presents a comprehensive approach to the production and evaluation of mycelium panels, taking into account their mechanical, thermal, economic and environmental properties. The research builds on previous studies that have highlighted the viability of these biomaterial advances by providing a detailed analysis of the specific conditions necessary for its manufacture and application in regions with hot and humid climates. It also explores the technical challenges and economic opportunities associated with its larger scale production.

Throughout this work, the methodology used is first explained, which includes the selection and treatment of agricultural waste, the inoculation of the mycelium and the formation of panels. In the results section, the values obtained in mechanical and thermal resistance tests are presented, complemented with a production cost analysis and an environmental impact scheme based on the product life cycle. The discussion analyzes the practical feasibility and possible limitations of the material, while the final reflection highlights its potential to transform current construction practices towards more responsible and sustainable models [3].

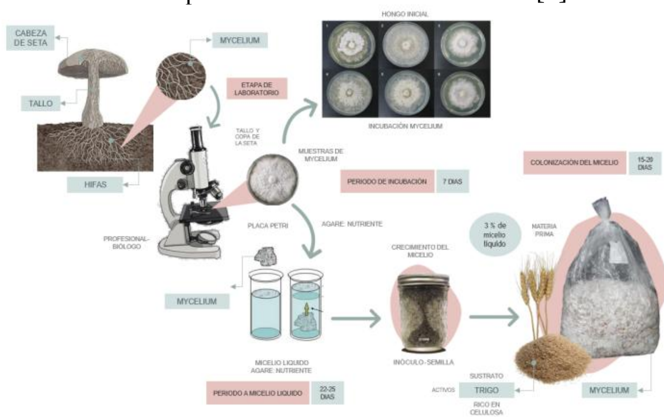

Fig. 2 Environmental productive scheme – Mycelio
Note. An economic contribution of mycelium in constructionr (Salas, 2023).

II. Materials and methods

The methodological approach of this research is based on the premise of developing a biomaterial suitable for hot and humid climate scenarios, where the demand for thermal insulation and humidity resistance plays a crucial role. The work plan was divided into stages ranging from the collection and preparation of agricultural waste to mechanical and thermal testing, including an analysis of costs and possible environmental impact. This holistic vision allows not only to validate the properties of the material itself, but also to understand its position within a value chain that aims to be more sustainable.

A. *Substrate selection and initial conditioning*

Identification and obtaining agricultural waste

It was decided to use wheat straw and pine sawdust. Such residues arise in abundance after grain harvesting and in wood processing in sawmills, respectively. From the circular economic approach, the use of this waste represents an opportunity to avoid its burning or disposal in landfills [4]. Agreements were made with local farmers and small sawmills to collect raw materials at low cost or free of charge.

Cleaning, crushing and drying

To optimize colonization by the mycelium, the impurities present in the straw (stones, plastic remains, large plant fragments) were eliminated. In the case of sawdust, it was passed through a sieve to discard excessively large particles or small metallic contaminants (nails, staples, etc.). Subsequently, the straw was chopped to maintain a size of 5-10 mm [5], thus facilitating its handling and uniformity in the mixing process.

To ensure proper humidity, both residues were dried at 60°C on extended trays, stirring regularly to avoid moisture retention at the bottom. These drying favors subsequent sterilization and reduce the risks of proliferation of unwanted fungi or bacteria.

Autoclave sterilization

After drying, the waste was packaged in polypropylene bags and placed in an autoclave at 121°C and 15 psi for 30 minutes. This process eliminates most competing microorganisms, creating a sterile or near-sterile environment for mycelium inoculation. It should be emphasized that sterilization constitutes a critical step: without it, the probability of contamination can increase exponentially, affecting the quality and resistance of the resulting panels.

B. *Inoculation and mycelium growth*

Fungal strain selection

The selected mycelium was Ganoderma lucidum, recognized for its rapid growth and the robustness of its filaments. Other fungal species have also shown notable potential, such as Pleurotus ostreat us or Fomesincentivius, but G. lucidum stands out for its ability to produce a dense and highly cohesive mycelial network, fundamental qualities for the formation of resistant panels.

Preparation of agar plates

Before inoculating large volumes of substrate, the strain was grown on malt extract-enriched agar (MEA) plates. These plates were incubated at 25°C and monitored for approximately 10 days, until complete colonization of the agar was achieved. In this way, pieces of mycelium in optimal condition were obtained, which later served as the basis for the main production batch.

Mycelium-substrate mixture and incubation conditions

With the sterilized substrate already cold, the mycelium was mixed in a 1:4 ratio (mycelium: substrate, on a dry basis) or 1:3 in some exploratory tests. The mixture was placed in perforated polypropylene bags, subsequently sealed to maintain an atmosphere with some air circulation. The assembly was placed in a chamber at 25°C and 60% relative humidity, under dim light conditions. For about 15 days, the mycelium expanded throughout the substrate, creating a cohesive whitish mass that indicated the presence of dense fungal filaments.

C. *Preparation of the panels*

Transfer to molds and compaction

Once the incubation was completed, the colonized substrate was transferred to 30 cm x 30 cm x 5 cm wooden or metal molds, which were previously disinfected with 70% ethanol. Compaction was carried out using manual presses or simple devices, with the aim of uniformly distributing the material. The degree of compaction influences the resulting density of the panel, a variable that, in turn, affects the mechanical resistance and insulation properties.

Partial consolidation in controlled environment

The molds were kept in an environment with a temperature of 22°C and humidity of approximately 60% for an additional 5 days. During this period, often called "controlled fruiting," the mycelium finished forming bridges between the substrate particles, reinforcing the structural integrity of the panel. It was monitored that no signs of contamination or excess humidity appeared that could favor the proliferation of undesirable molds.

Demolding and final drying

After this time, the panels were carefully removed from the mold to avoid breakage due to bending or traction. Then, they were placed in an oven at 50°C for 48 hours, reducing their moisture content to less than 10%. This drying effectively "inactivates" the growth of the mycelium, preventing it from reactivating in higher humidity conditions and favoring dimensional stability.

D. *Mechanical tests*

Compression resistance

To evaluate compressive strength, the ASTM D1037 standard, frequently applied to wood-based panels and boards, was followed [6]. Test tubes were extracted from each panel, taking care to preserve the integrity of the mycelial structure. A universal testing machine applied an axial load at 5 mm/min until the specimen collapsed. The maximum load value (in N) was recorded, and the breaking stress (in MPa) was calculated.

MOR and MOE in flexion

The bending test was carried out with three-point support. The sample was placed on two supports and the force was applied at the midpoint at a constant speed. The Modulus of Rupture (MOR), which indicates the maximum resistance before fracture, and the Modulus of Elasticity (MOE), which reflects the rigidity of the panel in the elastic section, were determined. These data allow us to understand if the panels would support bending forces in partitioning or interior covering applications.

E. *Thermal tests*

Determination of thermal conductivity (k)

The evaluation of thermal conductivity was carried out with a hot plate analyzer according to ISO 8302:1991. The panels were placed between two plates whose temperature difference was carefully controlled, measuring the thermal flow that passed through the material. In this way, the value of k (W/mK) was obtained, a crucial parameter to measure the effectiveness of the insulation.

Testing on wall prototypes

As an approximation to the real field application, test modules were built with walls that incorporated a layer of mycelial panels. A climatic chamber was used to subject these walls to differences in temperature and humidity, simulating daily conditions in a hot-humid environment. The objective was to quantify the reduction in heat transfer compared to walls without additional insulation.

F. *Analysis of economic and environmental feasibility*

Production cost calculation

The production of a standard panel (30 cm x 30 cm x 5 cm) involved costs of raw materials (agricultural waste, mycelium), labor (preparation, inoculation, growth monitoring), energy (sterilization, drying) and transportation. An average of USD 3.5 per panel was established under low-scale conditions. However, it is anticipated that industrial or semi-industrial production—with greater volume and process optimization—could lower the unit cost by up to 25% [6], [7].

Simplified Life Cycle Analysis (LCA)

A simplified LCA was undertaken to estimate the carbon footprint associated with the production of the panels. Among the phases contemplated were the obtaining of agricultural waste, the use of energy for sterilization and drying, and transportation logistics. Special importance was given to the possibility of composting the panels at the end of their useful life, which considerably reduces the environmental impact by avoiding disposal in landfills and allowing organic matter to return to the soil.

TABLA I

Comparison of mycelium with other building materials

COMPARISON OF MATERIALS IN THE ECUADORIAN CONSTRUCTION INDUSTRY

Element	Amount Unit	Architectural elements by price						
		Block / Cement	Metal	Tapial	Adobe	Bahareque	Guadua Cane	Recycled materials/ Imported
Foundations	m3	$275,00	-	$99,50	$88,40	-	-	-
Structures	kg	$26,20	$3,67	$19,10	$12,60	$9,90	$15,20	$25,80
Walls	m2	$5,20	$192,00	$11,10	$8,98	$8,00	$4,20	$20,20
Covers	m2	$14,20	$149,40	$15,00	$12,10	$12,80	$10,20	$38,90

III. RESULTS AND DISCUSSION

The following sections present the characteristic values obtained from the mechanical and thermal tests, as well as an overview of the economic feasibility and environmental impact that the incorporation of mycelium panels in the construction sector would have.

A. *Mechanical properties*

Compression resistance

The tested panels offered an average compressive strength of 1.2 MPa, with ranges from 1.0 to 1.4 MPa depending on the variation in compaction and density. Although the panels are not intended to withstand very high structural loads, their mechanical performance is sufficient to use them as interior enclosures, light partitions or even decorative ceilings.

Flexion: Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

The bending tests resulted in an average MOR value of 3.5 MPa. This indicates that the panels tolerate moderate bending stresses before fracturing. The MOE, close to 300 MPa, reflects acceptable stiffness, although it is lower than that of solid wood or OSB boards. However, in applications where high rigidity is not required (e.g. room dividers, decorations, internal insulation panels), these properties are adequate.

Observations on homogeneity

Density differences were noted in some panels linked to irregular compaction or variations in the mycelium colonization rate. These internal defects resulted in microcracks and localized reductions in strength. Precision compaction pressure and careful control of humidity during incubation were found to mitigate these inconsistencies.

B. Thermal properties

Thermal conductivity (k)

The panels showed an average thermal conductivity coefficient of 0.04 W/mK. This value is remarkably like that of glass wool or expanded polystyrene, recognized for their high insulating power. In hot and humid areas, this type of insulation can make a substantial difference in terms of reducing the heat that enters a home, mitigating the dependence on air conditioning or forced ventilation systems.

Tests with walls on a reduced scale

By integrating the panels into test walls, heat transfer decreased by about 30% compared to walls without any type of insulation. This tangible reduction in thermal flow represents potential energy savings and an increase in thermal comfort. Likewise, the lightness of the panels does not add significant loads to the structure, simplifying their installation and adaptation in low-budget works.

C. Economic viability

Direct production costs

Under small-scale conditions, each 30 cm x 30 cm x 5 cm panel reached a cost close to USD 3.5, considering the energy consumed in sterilization, drying and incubation, as well as the labor involved. The raw material (agricultural waste) can be almost free or at a very low cost, if agreements are established with local producers. The perspective of industrial scaling indicates that, by increasing the manufacturing volume, the unit cost could be reduced by at least 25%, approaching competitive values compared to other ecological insulators.

Local integration potential

The mycelium can constitute a dynamic agent of the local economy, by favoring the interaction between farmers, waste managers, work cooperatives and the construction sector. This would create a value chain that takes advantage of discarded organic matter and transforms it into panels with high added value. To achieve this, training initiatives and the existence of a minimum demand are required to guarantee the profitability of production.

D. Environmental analysis

Carbon footprint

By not requiring high temperature processes (beyond spot sterilization at 121°C and drying at 50°C), mycelium panels emit considerably less CO_2 than materials such as fired bricks or cement. Furthermore, the basis of production is based on the recycling of waste, mitigating the problem of its accumulation in landfills and avoiding its burning in the open air (a practice that can contribute to atmospheric pollution).

Composability and circular economy

Once the useful life of the panels has ended, their composting allows nutrients to be reincorporated into the soil, closing the life cycle in an environmentally friendly manner. Thus, one of the pillars of the circular economy is reflected, in which waste from one process becomes input for another, avoiding the negative impact associated with final disposal in landfills or landfills.

E. Discussion of the applicability of the material and its productivity in the local environment

The analyzed results show that mycelium panels provide a realistic opportunity to contribute to innovation in the construction sector. Although their resistance to compression and bending does not make them ideal for supporting high loads, they stand out as an alternative for interior walls, enclosure modules and thermal insulators that improve energy efficiency. This is especially relevant in hot and humid climates, where a large part of the electricity bill is allocated to cooling spaces and where humidity can easily damage materials that are not resistant to the proliferation of microorganisms.

The adoption of these panels depends, however, on various factors. Among them, it is worth mentioning the standardization of production, which requires careful control of humidity and temperature during incubation, as well as the pressure applied in compaction. Any deviation can give rise to heterogeneities that translate into significant variations in mechanical properties. For this reason, improvements are suggested in the automation of certain processes, such as pasteurization or inoculation, and the implementation of sensors that monitor the internal humidity of the panels while they consolidate.

On the other hand, social acceptance and regulatory validation are essential milestones for the scalability of this technology. Building regulators often require defined standards for durability, reaction to fire, moisture resistance, and other safety and health parameters. Mycelium, as a novel material, faces the challenge of demonstrating in standardized tests that meet the expectations of current building codes. Therefore, carrying out specific tests on fire resistance, behavior when absorbing prolonged humidity and potential for attack by pests is essential to legitimize its use.

Economically, feasibility lies in the proximity of the sources of agricultural waste, the accessibility of sterilization equipment and the cost of the mycelium. Likewise, the presence of public policies that encourage sustainable construction and the corporate social responsibility of some construction companies can pave the way for the introduction of this biomaterial into the market. The possibility of involving small agricultural producers in the provision of raw materials is notable, thus promoting job creation and local development [8].

Finally, the environmental focus marks an essential differential: not only is a low carbon footprint estimated in the production of the material, but the composability of the panels guarantees environmentally friendly disposal at the end of their cycle. This trait is becoming increasingly important in a society fighting the effects of global warming and high volumes of non-recyclable waste. Construction, traditionally considered one of the most resource-intensive activities, can greatly benefit from a paradigm shift that incorporates ecological regeneration instead of simple extraction and disposal.

II. Conclusions

The introduction of mycelium panels into construction represents a convergence of biotechnology and civil engineering that, just a few years ago, was considered almost futuristic. Today, laboratory tests and pilot experiences show that not only is it possible to manufacture these panels with relatively simple resources, but also that mechanical and thermal properties are obtained that are compatible with the demands of contemporary homes, if their function is limited to that of light enclosures and insulation. Lightness, potential low cost, composability and integration with the local economy make mycelium an ideal candidate for scenarios where people seek to reconcile the quality of life with the active protection of the natural environment.

However, there is a long way to go to refine production methodologies, validate the material before regulatory bodies and disseminate its benefits among end users. Part of this path involves multidisciplinary cooperation between microbiologists, engineers, architects, construction companies and, of course, the communities that could use these panels in their homes or production facilities. To the extent that these links are consolidated and more data on durability, fire resistance and behavior in conditions of high humidity are accumulated, mycelium will take a definitive step from laboratory innovation to its real integration into construction practice [9].

By not requiring high temperature processes (beyond spot sterilization at 121°C and drying at 50°C), mycelium panels emit considerably less CO_2 than materials such as fired bricks or cement. Furthermore, the basis of production is based on the recycling of waste, mitigating the problem of its accumulation in landfills and avoiding its burning in the open air (a practice that can contribute to atmospheric pollution).

Once the useful life of the panels has ended, their composting allows nutrients to be reincorporated into the soil, closing the life cycle in an environmentally friendly manner. Thus, one of the pillars of the circular economy is reflected, in which waste from one process becomes input for another, avoiding the negative impact associated with final disposal in landfills or landfills.

In short, mycelium is seen as an innovative biomaterial that could revolutionize the construction of social housing, by facilitating access to more sustainable and affordable solutions [10], [11]. The potential of this material to promote the circular economy lies in its natural origin, its low-impact production and its ability to rejoin the biological cycle after use. Multiple areas of research and development remain open to optimize its properties and ensure market acceptance, which, in the long term, could contribute significantly to the transformation of the construction industry towards more ecological and equitable models [12].

Acknowledgment

We thank the University of Guayaquil for permission to use its facilities in the systematization process through data simulation and experimental design of results.

References

[1] [1] T. Balaeș, B. M. Radu, and C. Tănase, "Mycelium-Composite Materials—A Promising Alternative to Plastics?," Journal of Fungi, vol. 9, no. 2, Feb. 2023, doi: 10.3390/JOF9020210.

[2] [2] W. Sun, M. Tajvidi, C. Howell, and C. G. Hunt, "Insight into mycelium-lignocellulosic bio-composites: Essential factors and properties," Compos Part A Appl Sci Manuf, vol. 161, Oct. 2022, doi: 10.1016/J.COMPOSITESA.2022.107125.

[3] [3] A. Bonenberg, M. Sydor, G. Cofta, B. Doczekalska, and K. Grygorowicz-Kosakowska, "Mycelium-Based Composite Materials: Study of Acceptance," Materials, vol. 16, no. 6, p. 2164, Mar. 2023, doi: 10.3390/ma16062164.

[4] [4] D. Alemu, M. Tafesse, and A. K. Mondal, "Mycelium-Based Composite: The Future Sustainable Biomaterial," Int J Biomater, vol. 2022, 2022, doi: 10.1155/2022/8401528.

[5] [5] Z. Zimele, I. Irbe, J. Grinins, O. Bikovens, A. Verovkins, and D. Bajare, "Novel mycelium-based biocomposites (Mbb) as building materials," J Renew Mater, vol. 8, no. 9, pp. 1067–1076, Jan. 2020, doi: 10.32604/jrm.2020.09646.

[6] [6] H. Vašatko, L. Gosch, J. Jauk, and M. Stavric, "Basic Research of Material Properties of Mycelium-Based Composites," Biomimetics, vol. 7, no. 2, p. 51, Jun. 2022, doi: 10.3390/biomimetics7020051.

[7] [7] A. Rigobello, C. Colmo, and P. Ayres, "Effect of Composition Strategies on Mycelium-Based Composites Flexural Behaviour," Biomimetics, vol. 7, no. 2, p. 53, Jun. 2022, doi: 10.3390/biomimetics7020053.

[8] [8] M. Sydor, A. Bonenberg, B. Doczekalska, and G. Cofta, "Mycelium-Based Composites in Art, Architecture, and Interior Design: A Review," Polymers (Basel), vol. 14, no. 1, p. 145, Jan. 2022, doi: 10.3390/polym14010145.

[9] [9] D. Lingam, S. Narayan, K. Mamun, and D. Charan, "Engineered mycelium-based composite materials: Comprehensive study of various properties and applications," Constr Build Mater, vol. 391, p. 131841, Aug. 2023, doi: 10.1016/j.conbuildmat.2023.131841.

[10][10] F. K. Lopez Duarte, “CIRCULAR ECONOMY ASSESSMENT IN DIFFERENT SCALES OF THE BUILT ENVIRONMENT Impacts and Sustainable Strategies[AVALIAÇÃO DA ECONOMIA CIRCULAR EM DIFERENTES ESCALAS DO AMBIENTE CONSTRUÍDO Impactos e estratégias sustentáveis],” Sustainable Mediterranean Construction, vol. 2021, no. 14, pp. 25–32, Jan. 2021.
[11][11] V. G. Shcherbak et al., “Circular economy and inclusion as effective tools to prevent ecological threats in rural areas during military operations,” Global Journal of Environmental Science and Management, vol. 10, no. 3, pp. 969–986, Jun. 2024, doi: 10.22034/gjesm.2024.03.03.
[12][12] S. Rinchen, S. Banihashemi, and S. Alkilani, “Driving digital transformation in construction: Strategic insights into building information modelling adoption in developing countries,” Project Leadership and Society, vol. 5, p. 100138, Dec. 2024, doi: 10.1016/j.plas.2024.100138.