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Product Design

TAPPING INTO NATURE'S BOUNTY

EXPLORING POSIDONIA OCEANICA ORGANIC WASTE FOR SUSTAINABLE MATERIAL DEVELOPMENT

Paula Mutiloa Martínez[*]

Abstract. This project addresses the need for sustainable materials in response to environmental degradation caused by human activity, particularly since the mid-20th century. Organic waste, such as Posidonia oceanica, significantly contributes to pollution and greenhouse gas emissions. The designer's role in addressing these challenges is highlighted, focusing on repurposing Posidonia oceanica waste into new materials. The study investigates the transformation of organic waste into usable composites, examining the feasibility of creating sustainable materials with unique properties. The primary goal is to use Posidonia oceanica waste as reinforcement in composite materials. Specific objectives include experimenting with biocomposites using mycelium, bio-cooking processes with gelatin, agar-agar, and Posidonia. The project follows five stages: information gathering and analysis, experimentation, testing, results compilation, and final documentation. A material innovation methodology, alongside non-standardised tests, was employed to confirm the hypothesis that a composite material could be made from Posidonia oceanica waste, including data on its potential combinations with other materials.

Keywords: Waste generation, organic waste, composite material, posidonia waste, material innovation.

Resumen. Este proyecto aborda la necesidad de materiales sostenibles como respuesta a la degradación ambiental causada por la actividad humana, particularmente desde mediados del siglo XX. Los residuos orgánicos, como la Posidonia oceanica, contribuyen significativamente a la contaminación y las emisiones de gases de efecto invernadero. Se destaca el papel del diseñador en la solución de estos desafíos, enfocándose en la reutilización de los desechos de Posidonia oceanica para la creación de nuevos materiales. El estudio investiga la transformación de los residuos orgánicos en compuestos utilizables, analizando la viabilidad de crear materiales sostenibles con propiedades únicas. El objetivo principal es utilizar los desechos de Posidonia oceanica como refuerzo en materiales compuestos. Los objetivos específicos incluyen la experimentación con biocompuestos utilizando micelio, procesos de biococción con gelatina, agar-agar y Posidonia. El proyecto sigue cinco etapas: recopilación y análisis de información, experimentación, pruebas, recopilación de resultados y documentación final. Se empleó una metodología de innovación de materiales, junto con pruebas no estandarizadas, para confirmar la hipótesis de que se podría crear un material compuesto a partir de los desechos de Posidonia oceanica, incluyendo datos sobre sus posibles combinaciones con otros materiales.

Palabras clave: *Generación de residuos, residuos orgánicos, material compuesto, residuos de posidonia, innovación de materiales.*

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1. INTRODUCTION AND OBJECTIVES

This study explores the potential use of Posidonia Oceanica organic waste as a reinforcing fibre in composite materials. The research emphasizes innovative experimentation to develop a materials library, focusing on DIY production techniques and the reuse of organic waste. A circular design approach is adopted to encourage self-production of biomaterials from organic by-products, supporting the circular economy and promoting sustainable urban production and consumption.

The project aims to optimize material formulations through specialized research and expert insights, investigating the properties of Posidonia fibres and their suitability for specific applications. By framing design as a political action, it seeks to align with regenerative design principles, ensuring environmentally positive outcomes. Furthermore, the initiative aspires to catalyse future academic and practical endeavours, fostering a more self-sufficient, collaborative, and sustainable community.

Main objectives:

- Use the "organic waste" of Posidonia as reinforcing fibre for possible composite materials.
- Generate a library of materials through an experimentation process.
- Promote the self-production of biomaterials and contribute to a circular economy.

Specific objectives:

- Determine the most appropriate formulas for the creation of materials.
- Show the project as a catalyst for change towards regenerative design.
- Open new avenues of research for future academic work or related projects, with the aim of expanding the positive impact and promoting a more sustainable community.

1.1. HYPOTHESIS

- A composite material can be generated with Posidonia waste.
- You can innovate with materials by being a product designer.

1.2. STATE OF THE ART

Currently, several authors have investigated the use of Posidonia fibers, both leaves and balls, as reinforcement for PHA bio-composites (Seggiani et al., 2017), as an additive in mortars (Saval Pérez, 2003), as reinforcement in bioplastics for packaging (Benito González et al., 2018)., as a material for the creation of boards (Maciá Mateu, 2016)., as a material for the production of composites with wood (Rammou et al., 2021)., as a basis for the creation of fiber boards (Garcia Garcia et al., 2018), among others, obtaining interesting results regarding physical and mechanical properties.

In these articles, we can see that the fibre treatment process is very similar; from the collection of the fibre, its subsequent washing and processing treatment. Depending on the matrix that joins the fibre, the properties are one or another. We highlight the insulating property, great capacity to absorb water (4.5 times its weight), fire resistance; it does not burn after 10 minutes in front of a Bunsen burner. (Saval Pérez, 2003, 426).

2. METHODOLOGY

This project applies the Design-Driven Material (DDM) methodology to experiment with and create a library of potential materials through iterative testing (Karana et al., 2015). It leverages expert recipes and Open Source platforms(Pérez & Gardey, 2023), including contributions from Kas Houthuijs, Shirley Niemans, Loes Bogers, and the HKU Lab Pastoe and Biolab, serving as foundational resources for experimentation.

The work follows a five-stage structure, prioritizing data collection and analysis in the initial phases and focusing on experimentation, prototyping, and results evaluation in later stages. Stage one employs state-of-the-art methodologies to explore material innovation and organic waste reuse. Stage two involves iterative experimentation, qualitative analysis, and expert evaluations to identify optimal material applications.

2.1. MATERIALS OVERVIEW

1. Posidonia: Harvested from Cala Roja, Ibiza, and processed through washing, boiling, and dehydration at 60°C for 5 hours.
2. Mycelium: Oyster mushroom mycelium was cultivated on agar and hemp at HKU IBB Biolab, producing soft, lightweight materials of medium hardness.
3. Polymer and Plasticizer: Two biopolymers were used—animal-derived gelatin for bioresin and agar agar (red algae) for bioplastic. Glycerine served as a plasticizer, influencing material flexibility and hardness, with properties adjusted by its concentration (Davis, 2017).

Image 1: Cleaning process of Posidonia leaves.

Image 2: Mycellium inoculated in agar agar and hemp.

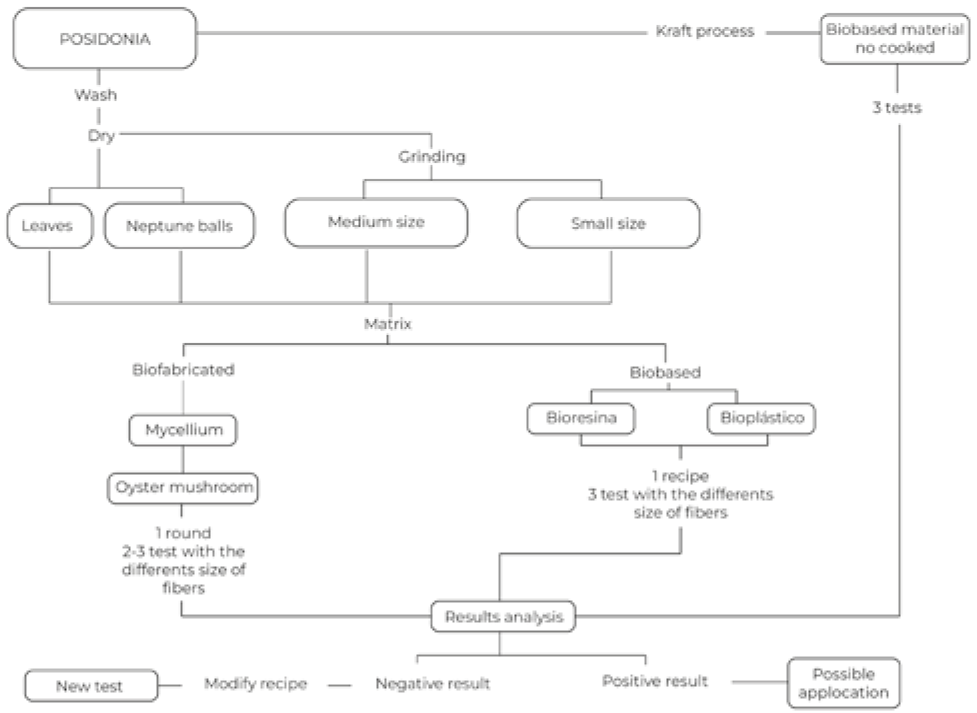

Image 3: Flow of methods.

2.2. MATERIALS AND TOOLS

The workspace and tools depend on the material type. Mycelium requires sterilized conditions achieved by cleaning with alcohol and using a blue-flame Bunsen burner. In contrast, cooked biocomposites require a ventilated space with electricity, and uncooked biomaterials need simple setups.

Biomaterials:

- Mycelium: Cultivated in sterilized environments.
- Cooked Biomaterials: Include bioresin (gelatin, glycerine, water) and bioplastic (agar agar, glycerine, water). In this case, the workspace is flexible, simple, with ventilation and electricity (if you use an electric stove).
- Uncooked Biomaterial: Made from Posidonia and water.

Samples are identified using a coding system based on material type: biocooked, uncooked, or biofabricated.

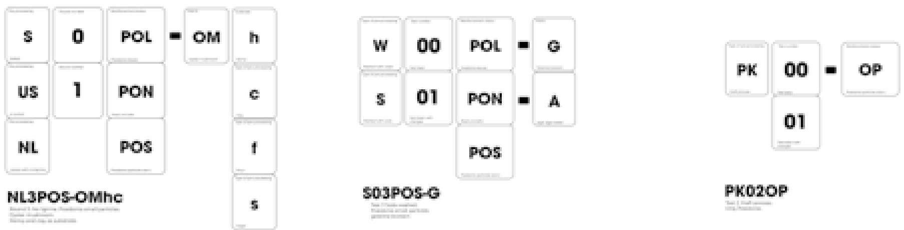

Image 4: Sampling code of the three different materials.

Analysis and Evaluation:
Tests follow specific criteria to refine formulations. Properties sheets document the results of cooked and uncooked materials, while the compatibility of the posidonia-mycelium matrix is assessed visually, classifying the results as optimal, partial or no growth.

2.3. CHRONOGRAM

The project timeline experienced deviations from the original plan. The research phase took longer than anticipated due to the difficulty in sourcing information on Posidonia as a material. Experimentation extended beyond initial expectations, as the iterative nature of testing and refining recipes made it an ongoing process. Conversely, the analysis phase was completed more efficiently than planned. Using organized tables streamlined the evaluation process, accelerating the drafting of conclusions and project layout.

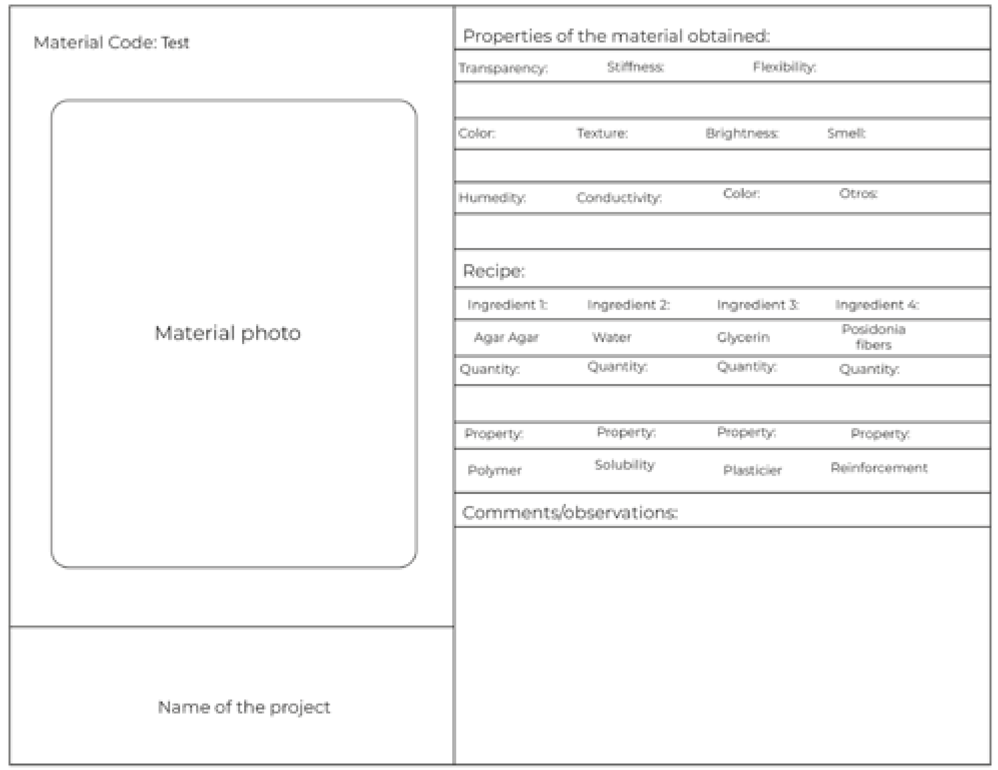

Image 5: Biobased evaluation sheet. Show the properties and the recipe of the material.

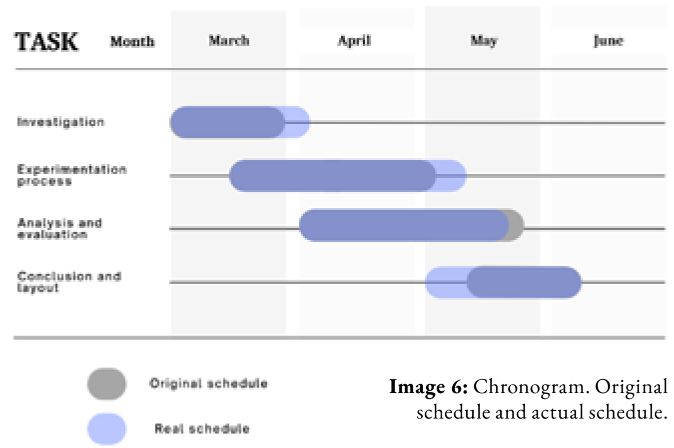

Image 6: Chronogram. Original schedule and actual schedule.

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3. RESULTS

Results are analysed in four sections: biofabricated material with mycelium, biocooked materials with gelatin and agar, uncooked biocomposites, and public feedback.

3.1. BIOFABRICATED: OYSTER MUSHROOM MYCELIUM

The study aimed to train mycelium to use Posidonia as a substrate. The primary hypothesis, "Posidonia can be used as a substrate for mycelium," was tested through secondary hypotheses. Initial experiments with raw Posidonia leaves were unsuccessful due to salt accumulation and high lignin content, which restricted mycelium access to cellulose. The Kraft process was explored to extract cellulose, and additional nutrients were introduced during growth, yielding mixed results. A final hypothesis, using a sugar, flour, and water emulsion to enhance growth, also proved ineffective.

3.2. BIOBASED: GELATIN, AGAR AGAR, AND POSIDONIA

The process progressed from raw Posidonia to final materials through iterative testing. Three tests per combination were conducted, totalling nine tests for each material type (18 overall). Results were documented using property sheets, cataloguing each material with codes and images, enabling systematic observation and analysis for iterative improvements.

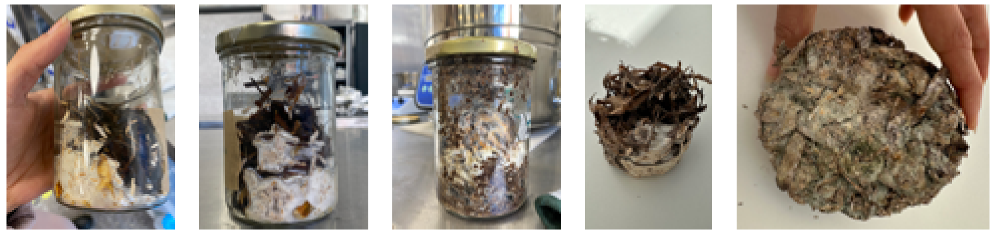

Image 7: Mycellium test: LPOLOM-h, LPOSOM-h, NL2POLOM-h, NL3POLOM-hfc and NLPOSOM-hfs.

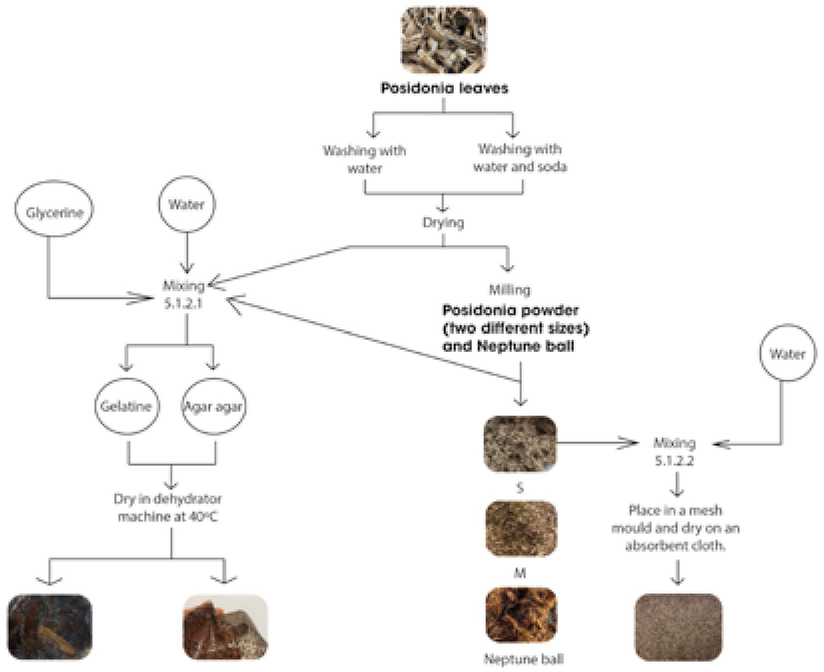

Image 8: Biobased experimentation process separated by cooked test and uncooked test.

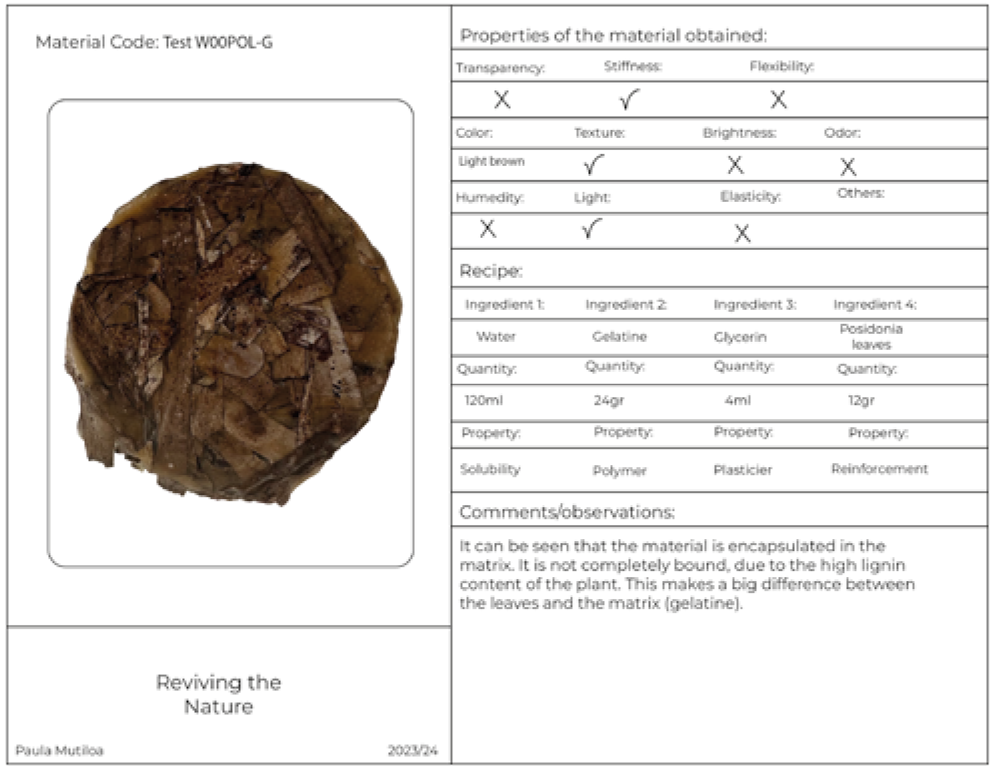

Image 9: Test W00POL-G. Made with gelatine.

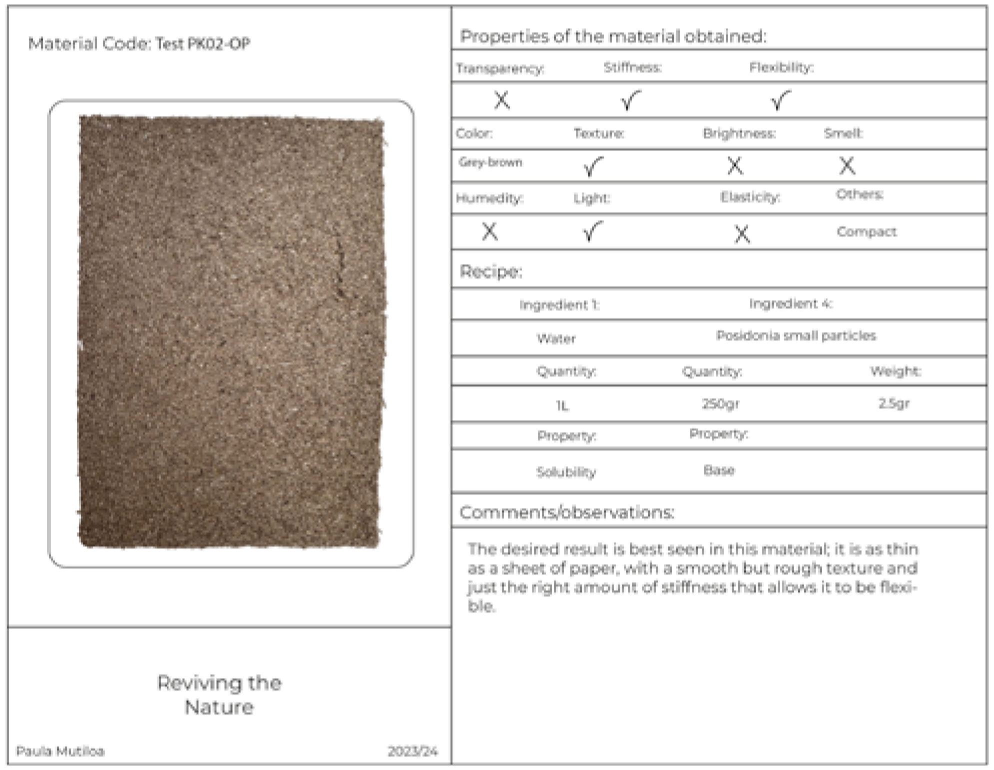

Image 10: Test PK02-OP. Paper from Posidonia fibre made through the Kraft process.

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3.3. RESULTS CONTRIBUTED BY THE PUBLIC

Regarding the results provided by the public (16 people in total), we obtained two types; one, related to the properties of each test (flexibility, roughness, bad smell, etc.), and another, refers to the possible future uses of the type of material; divided into four types: bioresin, bioplastic, paper/cardboard and mycelium.

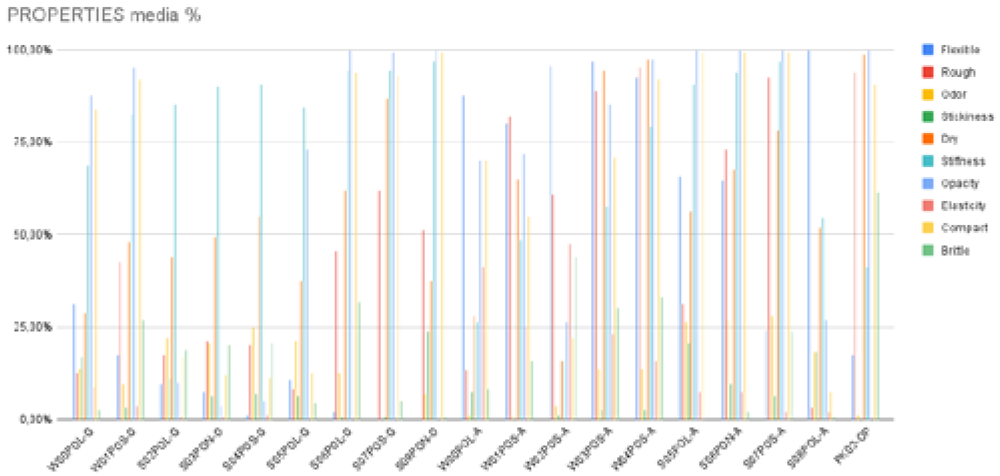

Image 11: Bar graph of the percentages of properties. The public's feedback through surveys in an exhibition of the materials.

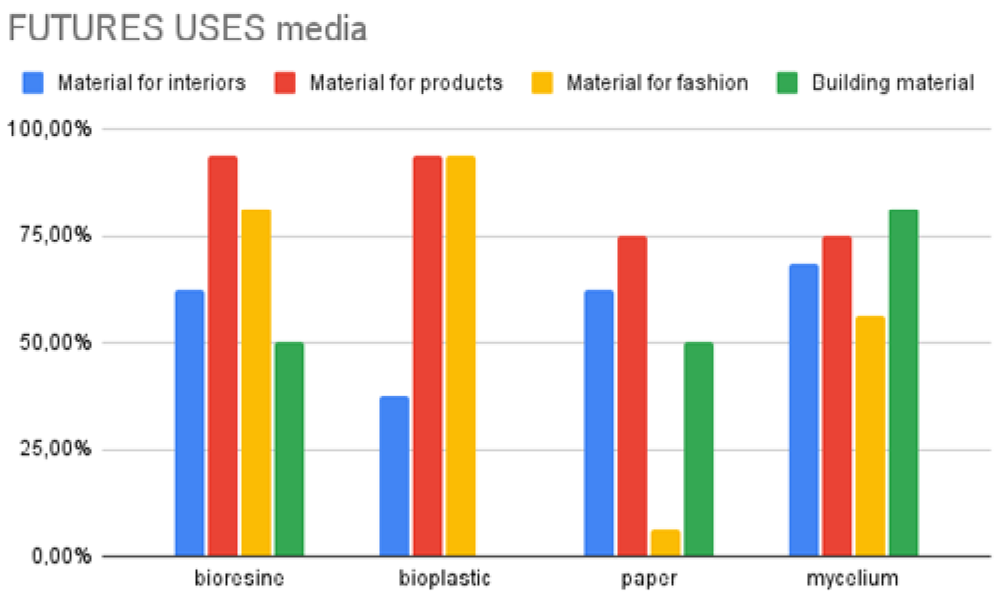

Image 12: Bar graph of future uses. The public's feedback through surveys in an exhibition of the materials.

4. CONCLUSIONS

This section presents the conclusions of the project, addressing general findings and experimental results, and proposing future research avenues. The initial hypothesis, "A composite material can be generated from the 'waste' of Posidonia Oceanica," guided the research and was validated through extensive investigation, experimentation, and analysis. Field studies confirmed the feasibility of using Posidonia fibre as reinforcement in composite biomaterials, demonstrating the potential for self-production in product design as both viable and innovative.

4.1. EXPERIMENTAL CONCLUSIONS

The experimental sub-objectives were successfully achieved, focusing on two key goals:

- Understanding the Material: Both theoretical and practical knowledge were gained. Theoretical understanding was drawn from technical literature, while practical knowledge was acquired through experimentation and design based on material characteristics.
- Determining Suitable Formulas: The most effective formulas for producing material samples were identified.

4.2. CONCLUSIONS FROM THE SAMPLES AND EXPERIMENTATION PROCESS

The self-production of biomaterials using Posidonia fibre was shown to be viable, resulting in materials with valuable properties. However, the Posidonia-oyster mushroom matrix proved unviable, yielding negative results. Long fibres arranged longitudinally or intertwined showed greater fatigue resistance and improved longitudinal elasticity. Neptune ball fibres provided higher stiffness and a rougher texture compared to other fibre types. Conventionally washed fibre did not bond well with the matrix, while fibre boiled with soda improved cohesion, resulting in better matrix bonding. A higher proportion of gelatin to glycerine produced a hard, resistant material, but not flexible or elastic, while using agar and increasing glycerine content resulted in a more flexible and elastic material, though less rigid and hard. Posidonia material was fragile and flexible but lacked elasticity and rigidity, limiting its application in product design.

4.3. FUTURE LINES OF RESEARCH

Two main research directions are proposed: the development of new materials and the application of these materials.

Development of new materials:

- Posidonia as a substrate for mycelium.
- Posidonia fibre composite biomaterials.
- Development of textile fibre from Posidonia.

Application of materials:

- Application of Posidonia biocompounds in products.
- Use of Posidonia as an insulating material.
- Use of Posidonia for packaging.
- Posidonia composite materials in space design.

4.4. PERSONAL APPRAISAL

After extensive research, it is evident that there is still much to explore, particularly in the area of DIY materials. The limited information on biomaterials related to Posidonia hindered a more precise analysis, which could have led to more defined objectives and results. However, this scarcity of data also underscores the value of this project, as it opens up opportunities for future researchers to build upon these findings, offering new research avenues.

I had the privilege of working in an excellent environment at HKU University Utrecht, with the guidance of expert teachers Shirley Niemans and Kas Houthuijs, who provided essential support. Despite dedicating significant time to experimenting with mycelium, I encountered a limitation of time that prevented me from exploring further in the field of cooked biomaterials, which could have yielded promising results. Early diversification of materials might have led to broader developments.

The Design Driven Material methodology was invaluable, providing clear structure and focus, particularly during experimental phases where it was easy to get sidetracked. This project has great potential and I plan to continue developing it. Despite challenges, these difficulties deepened my understanding of both the material and my own perseverance. They were crucial to my academic and personal growth. Moving forward, I aim to work collaboratively with specialists who share a passion for materials and use design as a tool for positive change.

5. BIBLIOGRAPHY

- Benito Gonzalez , I. , Lopez Rubio , A. , & Martinez Sanz , M. (2018). Potential of lignocellulosic fractions from Posidonia oceanica to improve barrier and mechanical properties of bio-based packaging materials. *International Journal of Biological Macromolecules, 118*, 542-551.https://doi.org/10.1016/j.ijbiomac.2018.06.052.
- Bogers, L. (2019). BIORESIN - *Loes Bogers*. https://class.textile-academy.org/2020/loes.bogers/files/recipes/bioresin/
- Davis, C. (2017, March 1). The secrets of bioplastic. Issue. https://issuu.com/nat_arc/docs/the_secrets_of_bioplastic_
- Garcia Garcia, D., Quiles Carrillo, L., Montanes, N., Fombuena, V., & Balart, R. (2018). Manufacturing and Characterization of Composite Fibreboards with Posidonia oceanica Wastes with an Environmentally-Friendly Binder from Epoxy Resin. *Materials, (11)*, 1-35. https://doi.org/10.3390/ma11010035
- HKU. (n.d.). *Making biomaterials*. LAb pastoe Gitbook. https://labpastoe.gitbook.io/lab-pastoe/tutorials/bioplastics
- Karana, E., Barati, B., Rognoli, V., & Zeeuw van der Laan, A. (2015). Material Driven Design (MDD): A Method to Design for Material Experiences. *International Journal of Design, 9*(2), 35-54.
- Maciá Mateu, A. (2016). Posidonia Oceanica boards and Galician pine wood particles. Study of mechanical properties. Compression parallel to the board. [Doctoral dissertation, Universitat d'Alacant]. http://hdl.handle.net/10045/54087
- Niemans, S. (2023). Biomaterials course. HKU Patoe, Utrecht, Netherlands.
- Pérez, J., Gardey, Ana. (2023, November 9). *Open source - Qué es, ejemplos, definición y concepto*. Definición.de. https://definicion.de/open-source/
- Rammou , E. , Mitani , A. , Ntalos ,, G. , Koutsianitis , D. , Taghiyari , H. R. , & Papadopoulos , A. N. (2021). The Potential Use of Seaweed (Posidonia oceanica) as an Alternative Lignocellulosic Raw Material for Wood Composites Manufacture. *Coatings, 11*(1), 1-69. https://doi.org/10.3390/coatings11010069
- Saval Pérez, J. M. (2003). *Study of Posidonia Oceanica residue used as additions in cement mortars*. [Doctoral dissertation, Universitat d'Alacant].
- Seggiani, M., Cinelli, P., Mallegni, N., Balestri, E., Puccini, M., Vitolo, S., Lardicci, C., & Lazzeri, A. (2017). New bio-composites based on polyhydroxyalkanoates and posidonia oceanica fibres for applications in a marine environment. *Materials, 10*(4), 326. https://doi.org/10.3390/ma10040326
- TomorrowBio. Insight. (2023, August 24). *Biotechnology. From polymers to ceramics: Different types of biomaterials and their uses*. https://www.tomorrow.bio/es/post/de-los-pol%C3%ADmeros-a-la-cer%C3%A1mica-diferentes-tipos-de-biomateriales-y-sus-usos-2023-08-5050879280-biotechnology