embryo-project | Design

Poster 1/2

DEBRIS

CiAUD Centro de Investigação em Arquitetura, Urbanismo e Design

FCT Fundação para a Ciência e a Tecnologia

Design Education on Biomaterial Research – Innovation from Surplus

Principal Investigator / PI
Gabriela Forman

Integrated Researchers of CIAUD
Michele Santos, Miguel Aboim, Aline Souza

Collaborating Researchers of CIAUD
Ana Neto

External Researchers
Arlete Apolinário

Keywords
Bioeconomy | Material-Driven Design | Biobased Materials

Partner Institutions
- Biolab Lisboa / FCUL;
- IFIMUP / FCUP

Expected Future Partner Institutions

ABSTRACT + IMAGES

DEBRIS project emerges from the need to accelerate research on by-product biobased materials and widen its use in Design. It consists of developing a network linking universities, bio labs and local industries to collaboratively build the conditions for Education on Bioeconomy Materials for Design, and further promote local partnerships for innovative businesses.

The current production model of consumer goods operates on an unsustainable cycle of material throughput and waste. On one hand, it is fueling an ever-increasing use of petroleum-based materials, despite the evidence of their negative impacts on the environment, biodiversity, climate change and human health. On the other hand, intensive production (predominantly, natural virgin raw materials) leads to deforestation, soil degradation and contamination, which in turn is related to food scarcity and less land availability to grow feeding crops [1]. To put it simply, we need to steer away from petroleum-based materials and avoid resource depletion. Moreover, global supply chains for the production of goods have grown more complex and are increasingly difficult to trace: materials from different origins are gathered for processing, sent to manufacturing, to finally be distributed to retailers around the world, later shipping it to the final consumer. This "out-of-sight, out-of-mind" system gives rise to poor labor practices in developing countries, as well as mindless raw material extraction and waste management, which are propelled by overconsumption. We have to bring production home so that we gain a sense of what it takes and how it impacts our surroundings.

Accordingly, this project aims to support the design field to widen the range of renewable resources used for Design artefacts, as material diversity can be a way to lift the pressure from our planetary boundaries. Biobased materials [2] can be made from renewable feedstock which can be retrieved from industry waste or surplus, making it an attractive strategy for material diversification coupled with waste management and resource optimization[1]. Thus, we aim to support the Bioeconomy in connection to local resources, as it can be a way to divert local industry by-products from landfill and contribute to new domestic supply chains (potentially less complex and more transparent) whilst nurturing mindful consumption (SDGs #9 & #12).

However, this transition can be a challenge due to the current disconnection of Design to materiality. Current Design fast paced practice leaves little space for experimentation and innovation in regards to the choice of materials. Design professionals and students have contact with a limited (most widely used) set of materials, curbing their creativity to what already exists and missing real design possibilities that new materials can trigger [3]. To create, designers must be familiarized with the materials to effectively grasp their possibilities of real applicability. Students and educators in the Design field are familiar with its relation with the Arts and even Business, but are less acquainted with its close link with Science, though the latter gears much of material innovation. Thus, our exploratory project questions: **How can designers become increasingly familiar with by-product biobased materials and participate more widely in the exploration of their applicability?** This will guide our exploration over potential conditions (logistic, material, human and educational) for students and educators in Design to learn and experiment with by-product biobased materials through a hands-on approach. We aim to set the stage to trigger designers' curiosity and nurture their literacy on biobased materials, encouraging the exploration of potential manipulation and uses, and the ability to engage in multidisciplinary projects within material innovation.

To this end, in the 12-month time-frame of the embryo-project, we set 3 specific tasks, to develop: (1) a stakeholders' network, (2) a Library/Archive of by-product biobased Materials, and (3) an Educational Plan in Education for Biobased-Materials for Design, based on preliminary work by the PI [4][5], and pilot test it. These points will be achieved through a mixed-method approach and include mapping potential stakeholders, case studies, laboratorial experiments and classification, and the development of educational strategies and tools (learning sessions and project briefings) to promote the discovery, assessment and innovation through by-product biobased material experimentation.

We expect the embryo-project's outcomes do contribute to a stronger research proposal towards a larger project, as it will enable us to better identify limitations, connections and opportunities for the future implementation of a strategic educational basis which can nurture the relationship between research and education in design and the industry within the challenges of the Bioeconomy.

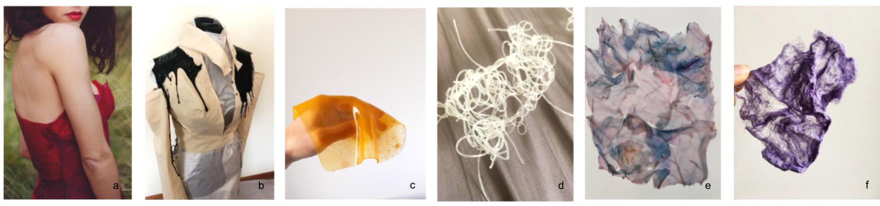


Fig. 1 – Some of the biobased (and biodegradable) experiments developed during 2016-2020 @ FAUL Design Courses [5]:

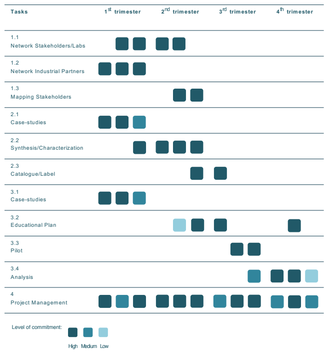
a) Bacterial Nanocellulose from tea fermentation and natural red dye applied on a performance arts video wadrobe, by G. Forman & B. Suarez
b) Charcoal waste and gelatin bioplastics, prototyping process, by G. Forman & N. Feliciano
c) Alginate, gelatin and natural yellow dye bioplastic sample, by G. Forman & M. Fidalgo
d) Starch waste bioplastic sample, by G. Forman & C. Duran
e) Paper-like sample made from vegetables waste, by G. Forman & H. Aguiar
f) Wool waste and bioplastic biocomposite sample, by G.Forman & T. Chambel

Table 1 - Resources and Outputs

Waste (biomass miscellaneous)	**Biofabricated Ingredients** (by bacteria, yeast, fungi, etc.)	**Algae** (micro/macro algae species)
✓ Seafood waste ✓ Fruits/Veggies waste ✓ Shells (from nuts, eggs, etc.) ✓ Olive and grape pomaces ✓ Coffee waste, etc.	✓ Biodyes, biopigments ✓ Bacterial nanocellulose ✓ Fungi-assembled material, etc.	✓ Agar-agar ✓ Carrageenan (kappa, iota, lambda) ✓ Alginate ✓ Chlorella, etc.

Possible outputs
Biofilms, biopolymers, (bio)composites, thread-like yarns (possible to extrude), gels, glues, resins and dyes/pigments, papyrus/paper-like materials.
Possible Industrial Applications
Textile, Construction, Product Design

Table 2 - Chronogram



OBJECTIVES

Offer an opportunity to educators and students to join forces and collaborate towards a broader understanding of innovative materials rising in popularity (their dynamics and relationship with society) and their potential to respond to societal challenges and industry demands. Therefore, project specific goals include the development of:

- 1# a stakeholders network, which can connect human, material and logistics resources. We aim to engage in first contacts to establish partnerships with local industries (for raw material supply); laboratories for learning and experimentation — there is already a partnership with BioLab Lisboa and FCUP —; and science/engineering professionals which can provide training on the subject;
- 2# the beginning of a library-archive of by-product biobased materials — biofabricated, biosynthesized — documented and labelled, as a learning tool;
- 3# a 1st Educational Plan on BioMaterial Experimentation for Design.

BIBLIOGRAPHIC REFERENCES

[1] Ellen MacArthur Foundation. (2017). *Urban Biocycles*. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Urban-Biocycles_EllenMacArthurFoundation_21-06-2017.pdf

[2] Biofabricate and Fashion for Good. (2020) *Understanding 'Bio' Material Innovation: a primer for the fashion industry*, Retrieved from: https://fashionforgood.com/wp-content/uploads/2020/12/Understanding-Bio-Material-Innovations-Report.pdf

[3] Zhou, Z. ;Rognoli, V. & Ayala-Garcia, C. (2018). *Educating designers through Materials Club*. 4th International Conference on Higher Education Advances (HEAd'18). Valencia, Spain

[4] Forman G. & Carvalho C. (2017). Circular economy and biological materials—innovative narratives for the development of sustainable textile products. In F.M. da Silva, H.M. Bártolo, P. Bártolo, R. Almendra, F. Roseta, H. A. Almeida & A. C. Lemos (Eds.) *Challenges for Technology Innovation - An Agenda for the Future* (pp. 445-450). DOI:10.1201/9781315198101

[5] Forman G. (accepted) Materials Towards Transition - Circularity in Fashion Design Education. *Journal Materials Circular Economy*, Springer

embryo-project | Design
Poster 2/2

DEBRIS

CiAUD Centro de Investigação em Arquitetura, Urbanismo e Design

FCT Fundação para a Ciência e a Tecnologia

SCIENTIFIC RELEVANCE FOR THE DISCIPLINE

Materials are part and parcel of the Design creative process. In turn, Design has a major influence in shaping our global material culture. However, materials selection is a complex task given their nature, variety and infinite properties, turning decision-making highly difficult during the creative stage. From an economic and environmental perspective, **every material choice has an impact**.

In this scenario, the Bioeconomy emerges as part of the Global Challenges defined by the European Agenda for Research and Innovation (Horizon Europe): biobased materials are, mostly, made from renewable resources (e.g. raw materials, waste and by-products from forestry, agriculture and/or the ocean, microorganisms) and can give rise to innovative circular markets.

Further knowledge on, experimentation with, and dissemination of, these emergent materials (often unknown territory for most designers) is paramount in **driving the shift from linearity to circularity** within the Design Field.

EXPECTED ECONOMIC AND SOCIAL IMPACT

The project will **nurture the relationships between research, education and the industry**, and is expected to impact all three economic, social and environmental spheres, as it aims to:

- **Encourage the innovative use of natural resources** as a way to create alternatives for petroleum-based, non-renewable materials. In the past decade, the field of emerging materials (particularly bio-based ones) has been steadily increasing. The importance of the Bioeconomy is discussed [6] as a key contributor to tackle major issues of the century, namely planet depletion, resource scarcity and climate change.
- **Divert local industry by-products** from landfill and **foster new domestic supply chains**, which can support responsible patterns of production and reduce resource depletion. The recovery and optimization of Portuguese resources — waste streams or by-products — from regional areas can additionally embrace cultural, geopolitical and historical perspectives, which strengthen social and economic dynamics.

RESEARCH PLAN AND TASKS

The research plan comprises **4 Tasks**, each divided into several activities. Tasks 1 and 2 will be carried out in parallel, as they will further influence each other. Task 3 will start as activities 1.3 and 2.3 are taking place. The purpose of these 3 tasks is to achieve each of the corresponding specific Objectives. Task 4 will be ongoing throughout the project.

Task 1. Mapping Stakeholders

1.1 Field work in labs. This activity aims to build a network of labs providing space and experimentation tools for various processes; this is important to establish the laboratorial/logistics and human resources (e.g., engineering professionals, educators), key for activity 1.3.

1.2 Field work in the industry to identify potential by-products and companies for partnerships (this entails missions such as visits to facilities and/or meetings). This activity aims to establish a network of industry partners which can provide "ingredients" (by-products, such as agro-industrial biomass residue) sourced locally, within the region. This activity is paramount to strengthen the continuity (or future feasibility) of the project and it will be important for activity 1.3.

1.3 Map current stakeholders and analyze opportunities and limitations for laboratorial experimentation (equipment availability, laboratorial conditions and materials will shape the territory of exploration). This is important to identify the possibilities for activities 2.2 and 3.3.

Expected outcome: a map of national industry partnerships (for by-products supply) and universities/laboratories that can be established for a larger research project. This will include opportunities and limitations for laboratorial experimentation, shaping future research proposals.

Researchers involved: GF, AS, MS

Task 2. Develop a pilot library-archive of biobased materials

2.1 Case studies. This activity includes trips to two international labs and meetings in order to identify the challenges and limitations, and understand the nuances of implementing such a project (materials and processes wise), related methodologies and research strategies.

2.2 Develop a set of 5 by-product biobased materials. Materials in the library will show the diversity of potential outcomes of experimentation, such as biofilms, biopolymers, (bio)composites, thread-like yarn (possible to extrude), gels, glues, resins and dyes/pigments.

a) Synthesis stage @ Biolab Lisboa: sample development (documenting steps, processes, tools, properties, etc. by photo, video, writing methods). We will focus on the fabrication of a minimum of 5 samples (from 5 recipes) related to three main resources (see Table 1):

i) By-products from various waste streams
ii) Biofabricated ingredients
iii) Algae species

b) Characterization stage @ IFIMUP/FCUP, which has a strong background in Material characterization and advanced laboratorial facilities (state-of-the-art equipment at national and international level): samples will be sent by post to IFIMUP lab in Oporto and will be tested to evaluate material performance; these will additionally be characterized on the following — constituents (ingredients), sensorial properties (smell, tactile aspects), aesthetics (appearance, color, shape, gloss, texture…), maintenance aspects. Detailed material science tests and characterization are imperative approaches to grasp real industrial applicability; some of the technical properties to be studied include tensile strength, weight, density, porosity, structure, chemical resistance and stability, hydrophobic behavior amongst others, and will be performed by techniques such as AFM nanoindentation, high-resolution electron scanning microscopy, EDS and FTIR.

2.3 Catalogue each material [description, properties, "ingredients and recipe", potential applications] physically (digitally in the future). Results of activity 2.2 will be labelled, documented (through video and photography) and properties described in simple terms, for replicability (visually appealing, in an infographic manner). These tags need to be able to undergo transformation by peers (e.g., updates, reviews, considerations, tips, suggestions, discuss factors such as timings, effective utilization and biodegradability). While it is planned to have a physical showcase in this embryo-project, we aim to make these resources available on an open-source online platform in future stages of the project.

These activities should respond to goal 2# and provide the basis for a bio-materials library (as an educational tool) to develop in future stages of the project.

Expected outcome: a showcase of 5 by-product biobased material samples, categorized and labelled (including a documented process to allow for replicability), as the beginning of the Biobased Material Library/Archive.

Researchers involved: GF, AA, MA

Task 3. Developing an Educational Plan

3.1 Case studies, related to 2.1, but focused on the educational aspects of Design/Science synergy. This will inform activity 3.2.

3.2 Creating a 5-session educational plan with exercise briefings for both students and educators. We aim to develop these briefings based on Discovery Learning, as the audience should be able to observe, explore, manipulate, process, document and transform raw materials. This hands-on approach can stimulate further questions and prompt in-depth knowledge on potential ingredients for material synthesis and manipulation; focused on the DIY and/or DIT style and related dynamics (ideal for students/designers), to be used in critical material imaginaries, question/create different aesthetic concepts and push sustainability forward.

3.3 Piloting laboratorial sessions. A group of students and educators will be recruited to take part in the sessions planned in activity 3.2, @ Bio Lab Lisboa.

3.4 Evaluating pilot outcomes and revising briefings (3.2) and educational materials (2.3).

These activities should respond to goal 3# and provide the basis for an educational plan to develop and implement in future stages of the project.

Expected outcomes: an Educational Plan for Biobased Materials for Design, for five laboratorial sessions for design students and educators; an analysis of the pilot-session, further shaping the educational plan, and translated into one article for publication, to disseminate the project.

Researchers involved: GF, AA, MS

Task 4. Planning and Management

This task runs throughout the project, supporting and ensuring all other tasks are carried out in a timely manner so the project achieves its objectives within the set timeframe.

4.1 Planning: defining the timeline and providing organizational support to team members in their activities, defining activity alternatives when issues arise, costs overview.

4.2 Management: coordination of the project, distributing activities among team members, quarterly progress checks.

Expected outcome: the Project Report.

Researchers involved: GF, AN

Critical Factors of Success and Risks: The interdisciplinarity of the team (Science and Design), together with the laboratorial conditions provided by the already established partnerships with BioLab Lisboa and IFIMUP/FCUP are considered the critical factors of success of this embryo-project. As the current pandemic may impose mobility restrictions at any time, the biggest risk of this project concerns the international trips needed for the case studies: while these trips are planned for the beginning of the project (to inform the rest of the embryo project), they may be made at a later stage and still provide a valuable contribution to strengthening our project for future submissions to funding.

EXPECTED SCIENTIFIC RESULTS

Expected outcomes include the creation of a networking of partners with different backgrounds and capacities/capabilities, supporting each other and the project towards:

- Identifying/recognizing connections, gaps, obstacles, opportunities;
- An educational plan based on interdisciplinary practices and methodologies – Design modules and briefings to implement in the pilot workshop with students and educators;
- A set number of 5 recipes, replicable or able to undergo improvement/manipulation in the experimental stage (students and educators will explore them under guidance);
- Materials/biocomposites (categorized and labelled) - results from laboratorial experiments created in the exploratory phase – data-base, informative material archive, with industrial applicability in the fields of Product Design, Textiles and Architecture;
- Report and further dissemination discussing the experience and outcomes as well as main conclusions/takeaways.

BUDGET: € 7.499,00

Acquisitions: Laptop, needed throughout the project (Macbook Pro 16" Processor Intel Core i7 2,6 GHz; Turbo Boost 4,5 GHz, AMD Radeon Pro 5300M; 16 GB RAM, 512 GB storage SSD, or similar): **2799€**
Mission 1: 2 researchers commuting (CP train trips/Lisbon-Oporto) for meetings with 3 national prospect stakeholders, concerning activity 1.2: **390€**
Mission 2: 2 researchers travelling to two international BioLabs, related to the case study in activities 2.1 and 3.1:
M2.1) Barcelona Lab: trip, mobility and housing: **360€**
M2.2) Green Lab London: trip, mobility and housing: **700€**
Materials/Consumables: Ingredients and tools to process the industry by-products (fungi, bacterium, yeast; grinders, blenders etc.), needed for activities 2.2 and 3.3: **3000€**
Print Materials: the educational tools in activities 2.3 and 3.1 will be in physical format: **50€**
Postal Services: to ship materials and small lab equipment between labs (Biolab/FCUL in Lisbon and IFIMUP/FCUP in Oporto) related to activities 2.2, 2.3 and 3.3: **200€**