CIRCE

Creative Fellow

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Report on Mattering – Paste and Pour

CIRCE Creative Impact Research Centre Europe

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REPORT ON MATTERING - PASTE AND POUR

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1. 3D printed structures from developing process.

1 UNLOCKING TRANSFORMATIVE POTENTIAL

Within the dynamic landscapes of cultural and creative economies, this project presents a profound insight: the transformative potential of biomaterial innovation. It offers a deep dive into the creative processes, resource reimagining, emergent material properties, and the concept of Nutrient Materials. These insights illuminate how biomaterials from agricultural and food production waste can reshape our approach to creativity, sustainability, and circularity.

A journey through creative transformation

At its core, this creative project underscores that biomaterials are not merely materials but agents of transformation. Born from often overlooked agricultural and food production residuals, the developed materials can contribute to sustainable practices within cultural and creative economies.
It emphasizes the value of a practice-based, iterative research approach. This dynamic approach uncovers unexpected material properties and applications, emphasizing that the results are not an endpoint but part of a transformative process that nurtures ideas and sparks change.

A reconsidered concept of matter and circular material diversity

The research spotlights a reconsidered concept of matter. It champions the potential of waste and residuals as the core ingredients for crafting edible and compostable biomaterials. In the context of the creative economy, it becomes evident that designers have the power to contribute to circular material diversity and foster sustainability by reconsidering underutilized resources.

Emergence of unique material properties

Excitingly, the project delves into an alchemy of biomaterials. When combined with specific technologies, particularly the paste extrusion 3D printing process, these materials give birth to unique emergent properties. These properties become wellsprings of innovation, offering solutions that range from unbreakable 3D-printed objects to flexible films. Biomaterials, it becomes clear, deliver a versatile palette of qualities and sensory experiences that breathe new life into the future material range.

Nutrient materials for circular living

This narrative introduces the concept of "nutrient materials." These materials encapsulate the potential of circularity. They are edible for living matter, seamlessly aligning with sustainable practices. Their essence lies in a beautiful duality – they can be used and consumed and then gracefully returned to the natural cycle as fertilizer, nurturing the birth of new resources.

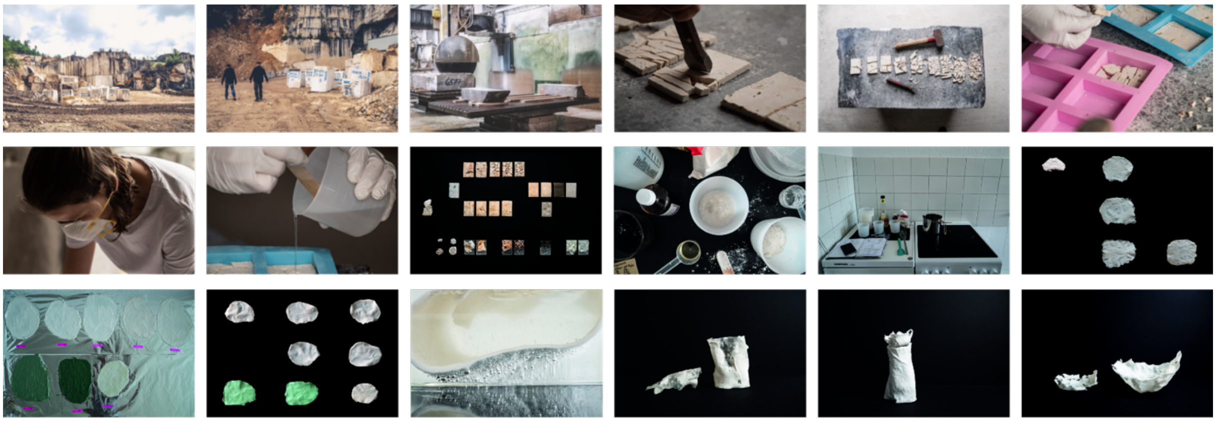
Pioneering sustainable biomaterials in cultural and creative economies

The Mattering Project yields insights with significant implications for cultural and creative economies, aligning with the goals of CIRCE. It demonstrates how sustainable biomaterials can drive transformative change, promoting sustainability and circularity in these sectors. Interdisciplinarity is essential for such innovation and serves as a model for addressing complex challenges. Scalability is crucial for resilience, supporting decentralized on-demand manufacturing. Biomaterials inherently support circular principles, contributing to soil regeneration and sustainable practices. These insights may inspire other projects and inform policymaking to accelerate the adoption of sustainable biomaterials and foster innovation in cultural and creative sectors. Europe's cultural and creative economies have the potential to lead in sustainability and contribute to a regenerative future, setting an example for other industries in the transition to a circular economy.

What follows is a journey through creativity, innovation, sustainability, and circularity. It champions biomaterials as the catalysts for redefining our relationship with materials and propelling us toward optimistic future scenarios and ways out of multiple crises.

2 MATTERING – MEAL BAG AND A RECONSIDERATION OF THE CONCEPT OF MATTER

2. Project Mattering - Meal Bag: pictures from journey and thought models.



2.1 Introducing the Mattering Project: investigating the essence of matter

The Mattering Project began during the Product Design Master program at the University of Arts in Berlin in 2019. Unlike typical projects that focus on solving issues, Mattering embarked on an extraordinary journey to investigate the fundamental nature of matter - the underlying substance that forms our physical world.

Guided by thought models, the project ventured into the territories of materiality. These thought models served as a canvas for visualizing profound considerations about matter, paving the way for an unconventional material approach. In doing so, they facilitated personal insights and fostered an understanding of where the application of self-developed biomaterials could yield the most profound benefits.

At its core, Mattering is an ongoing conversation with matter itself. Through constant dialogue, the narrative of the project, exemplified by the Meal Bag - an innovative concept for food packaging – delves into the imaginable realm. It merges the domains of biomaterial substance research with a theoretical exploration of the role of matter in our contemporary era.

The final material of this first exploration formed the Meal Bag - an edible food packaging designed to promote conscious consumption over disposal. What sets the Meal Bag apart from conventional bioplastics like PLA (biodegradable bioplastic often made from cornstarch) is its remarkable ability to dissolve in hot water after use, making it edible.

The extraordinary potential to transform the unimaginable into reality is unlocked through the attentive observation of matters' behavior and communication. This process is rooted in a reconsidered concept of matter for living in harmony with nature and recognizing our interconnectedness with the material-based world. It echoes the profound notion that "We are all compost,"[1] underscoring our collective responsibility in shaping a sustainable future.

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[1] Haraway, D. (2016) Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.

2.2 Exploring the metamorphic power of matter

At the heart of the Mattering Projects' origins lies an exploration of limestone, which has traversed eons of geological and ecological history. This mineral, sourced from a local quarry, is the foundational medium for the initial physical thought model. Its profound journey begins in the depths of an ancient ocean, where living matter played a vital role in its creation.

Millions of years ago, limestone emerged as a product of natures' symphony - a delicate interplay of symbiotic organisms, Earths' cyclical matter transformations, and chemical reactions. Calcium carbonate, the building block of stone coral skeletons, is formed through these intricate processes. In this dance of existence, carbon was released into the surrounding waters, becoming a vital resource for symbiotic single-celled algae known as Zooxanthellae. These tiny organisms use it to generate biomass through photosynthesis, a crucial contribution to Earths' ever-evolving ecosystem. Without this activity, the carbon dioxide around the coral would again react with its skeleton and dissolve it. Thanks to the algae, the corals survived, and their skeleton was able to continue its metamorphosis. Remarkably, the work of the algae made the previously inhospitable air above water breathable, enabling terrestrial life to flourish and humans to evolve. Millions of years later, and by the cycle of stones, calcium carbonate came back as limestone from the inner to the surface.

Beyond its impact as an oxygen producer, the one-cell algae assumed a further role of monumental consequence. Their biomass metamorphosed into fossil oil over unfathomable periods and countless enigmatic transformations. This newfound resource marked a pivotal moment in human history, propelling the acceleration of our evolution and the globalization of our species.

2.3 The Anthropocene and manipulated matter

As humans expanded on Earth and began manipulating matter at molecular and atomic levels, a very young sphere on Earth evolved further - the Anthroposphere. Today, this sphere dominates most other spheres on Earth, such as hydrosphere, lithosphere, or ecosphere. This area reflects the human impact on Earth and matter.

Humanity aspired to assert dominance over nature, first to survive, to secure the life of its descendants, and finally to shape it to meet our ever-expanding needs. The once-abstract concept of matter was now inexorably tied to specific controlled materials and resources, morphing into a passive entity awaiting manipulation.

The consequences of this mastery over matter resonate more than ever in the Anthropocene. This era showcases the non-reversible human causes on Earth. Human-induced climate change, with its far-reaching repercussions, has brought about unprecedented shifts in Earth's living conditions. Explosive population growth, natural resource exploitation, fracking, and escalating environmental pollution have triggered ecological challenges - resource scarcity, water shortages, ocean acidification, species loss, environmental catastrophes, and rising carbon dioxide levels.

In the face of these destructive forces, fundamentally reconsidering our concept of matter could be a game changer. The path forward may require a transformative shift in our relationship with materials, reflecting the essence of the Mattering Project itself - a quest to explore, understand, and redefine our interaction with the very nature of our world, matter.

2.4 A reconsideration of the concept of matter

Understanding the essence of "matter" necessitates deeply examining its interactions within the intricate tapestry of the natural world. Take, for instance, the metamorphosis of limestone - an exemplar of living and non-living matter circulating through the Earth's spheres actively co-shaping the globe. However, there is also a darker side to the limestone story, illustrated by the plastic pollution caused by human materials made from fossil oil and spread by weathering and the activities of living matter and their metabolisms. Matter operates on a perpetual cycle of creation and dissolution, indifferent to humans.

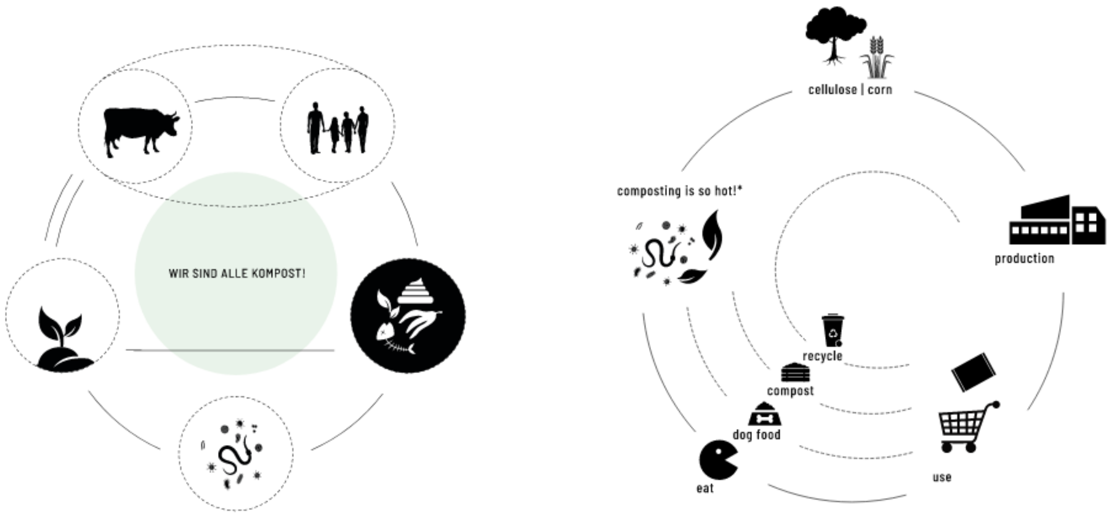
Living matter, organisms, and open systems are integral players in this intricate dance, tirelessly striving to maintain equilibrium, foster growth, and perpetuate reproduction. The Earths' surface is the canvas upon which this interconnected narrative unfolds - a complex web of material relationships, connections, and metabolic reactions. Human territory, the Anthroposphere, leaves irreversible scars upon this fabric and calls out the Anthropocene era, characterized by the reality of climate change and resource depletion. These challenges defy immediate solutions, necessitating a multi-generational commitment to Earths' regeneration.

Reenvisioning our understanding of matter unveils its inherent forces – one of the remarkable main substances of the universe serving as the building blocks of our physical world and of growth, perpetually coursing through Earth's spheres and fueling the planets' metabolic processes. It metamorphoses into compost, breathing new life into cycles, forging and dissolving connections ceaselessly. Matter is adaptive, responsive, and dynamic, shaping our physical world through a complex interplay within and through open systems and its circulation through all Earths' spheres.

An inclusive perspective on matter opens the door to a realm of boundless possibilities, transcending the domain of scientific inquiry. It implores us to observe, experiment, reflect, and, most crucially, take ethical action. This moral imperative extends to considering the profound impact made by humans on material cycles, preserving the foundations of growth, and nurturing the evolutionary narrative. In all its forms, matter narrates its story, unveiling its vast potential and myriad possibilities. Ethical action, in turn, entails a conscientious response to these opportunities, whether they involve interaction with other species, entities, symbiotic relationships, or Earths' interconnected systems.

Ultimately, we coexist with nature in a symbiotic relationship. The transformation of our understanding of matter represents not a superficial alteration but a gradual process of healing - a profound reshaping of our interactions with the living and non-living entities of our world. As the demands of technical materials recede into the background, nature takes center stage, and humanity assumes its place within the broader tapestry of metabolisms and metamorphosis.

3. Graphics of metabolisms and cycle of matter.



2.5 Meal Bag - A representation of a reconsidered concept of matter

The Meal Bag represents edible food packaging, fundamentally challenging conventional notions of packaging materials. Comprising edible ingredients akin to paper, it has airtight properties and a degree of resistance to moisture. The compound dissolves when submerged in hot water, seamlessly integrating with meals. One of its primary components is cornstarch, which functions as a sauce thickener during cooking.

4. Meal Bag manufacturing process. m: Meal Bag Porridge. r: Meal Bag Penne al Arrabiata.

Beyond its practicality, the Meal Bag is a valuable source of fiber and energy, positioning it as a constructive addition to the food chain rather than a hazardous waste product. Its distinctive attributes include edibility, compostability, rapid degradation, renewability, and recyclability, offering a promising pathway toward a closed-loop materials cycle while allowing for spontaneous action.

In 2017, the Federal Environment Agency reported an alarming statistic: approximately 107 kilograms of packaging waste were generated per private individual. Alarmingly, only 49.7 percent of plastic packaging was recycled. Regrettably, the proliferation of plastic packaging, especially in the food sector, continues unabated. While forward-thinking concepts like zero-waste stores provide valuable guidance for a packaging-free lifestyle, integrating such practices into the daily routine remains challenging for many. It necessitates meticulous planning and carrying suitable containers for loose food items.

The Meal Bag, however, strikes a harmonious balance. It serves as a dispenser, protecting contents from external influences while preserving an airtight seal. Crucially, its edibility ensures that it can be repurposed after initial use. Like cleaning vegetables, a simple wash precedes its transformation into foundational ingredients for sauces. As a result, sustainable consumption can be effortlessly embraced, even amidst the demands of a busy lifestyle.

5. Meal Bag samples

The consumer's choices govern the closure of the material cycle, emphasizing that the enclosed components can circulate to become new materials. The Meal Bag concept has the potential to prompt a fundamental reconsideration of packaging attitudes and foster a deeper appreciation for materials. It can raise environmental consciousness among those for whom immediate change might be challenging, facilitating gradual shifts toward responsible consumption practices.

6. l: Meal Bag empty packaging samples and films. r: Meal Bag film weathering process.

2.6 Designers as alchemists: navigating the transformative journey with matter

The development of the Meal Bag serves as a vivid testament to designers' ever-evolving relationship with materials. This journey is marked by continuous self-reflection and adaptation as designers engage in relentless experimentation and contemplation. They uncover fresh insights into material compositions and behaviors, fostering an ongoing dialogue with matter itself. This transformation into material alchemists equips them to interact responsibly with the natural world.

Designers as alchemists differ significantly from the traditional. Their holistic and ecological approach focuses on matter's constant state of transformation. They closely observe, experiment, and explore its potential, becoming temporary companions to matter. This expanded perspective delves into ecosystems, symbiotic relationships, material attributes, and system dynamics, actively participating in the process.

The alchemist's awareness spans macro and micro cycles. Design becomes an interdisciplinary practice of material alchemy, involving a deep understanding of matter's language, emergence, dissolution dynamics, and behavioral patterns. They recognize the interconnections and substance cycles that shape our intricate global organism - Earth.
With this knowledge comes ethical responsibility. Alchemists guide transformations into realms of possibility, deciding which potentials materialize and how they are communicated. Their role extends to influencing culture and its evolution through knowledge sharing.

In this transformational journey, designers embrace their roles as alchemists, navigating matter's intricate cycles and complexities, fostering sustainable and ethical design practices, and shaping culture by sharing their evolution of knowledge.

2.7 Mattering - Further exploration of possibilities

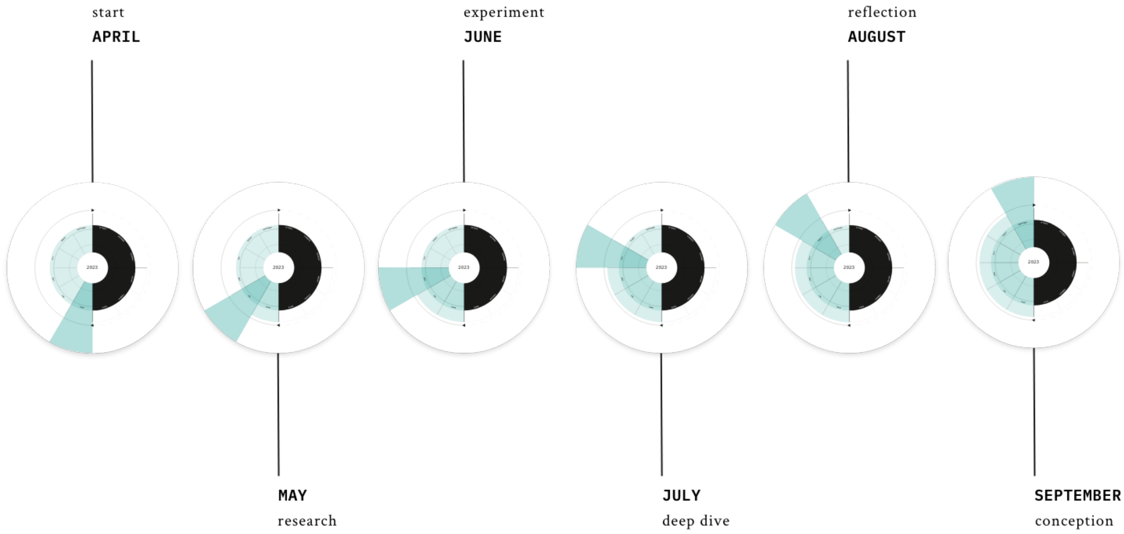
The roots of the Mattering Project lie in the unceasing curiosity of those who aspired not only to understand but also to reconsider the essence of our world - matter. Its further development in 2020, following the master's year at the University of Arts, initiated a ceaseless endeavor to unlock the potential inherent in biomaterials.

Mattering - Paste & Pour is pushing the boundaries of the conventional insights surrounding materials. From pioneering innovative recipes for pouring biomaterial foils and 3D printing pastes utilizing residuals from agriculture and the food industry, the project has ventured into experimental territories within biomaterial design.
Beyond material experimentation, the project has cast a wide investigative net, encompassing policy, legislation, strategies, trends, economic dynamics, industrial landscapes, start-up ecosystems, cultural shifts, raw materials, residuals, and material innovations. It embodies a holistic approach that interconnects these diverse facets into a comprehensive exploration.
The goal is to illuminate the potential latent within biomaterials and to forge a sustainable and harmonious relationship with the materials that shape our world.

A substance precedes every object. It determines its behavior and influences its impact on a becoming world.

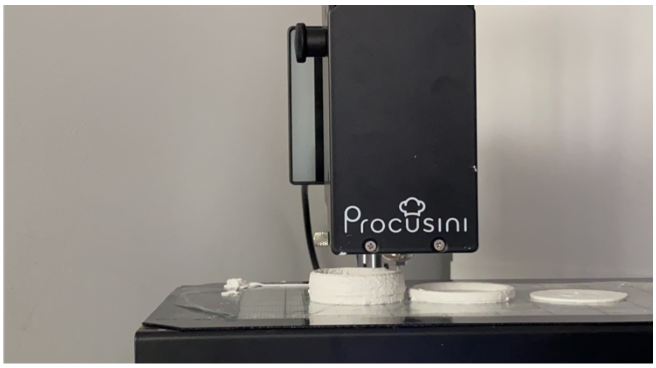
3 PROCESS MATTERS - PROCESS AND DEVELOPMENT

7. Process from April to September overview.



Exploring biomaterial matters unfolds as a practice-based research quest, evaluating the potential of residual and waste materials from agriculture and food production. It delves into scalable manufacturing processes, here called "Paste" (paste extrusion 3D printing) and "Pour" (pouring foils). The process follows an experimental and artistic practice guided by systemic iterative methods with an open end. While reflecting on the process and gleaning insights, a journey culminates in transformative material concepts, all within the context of current issues.

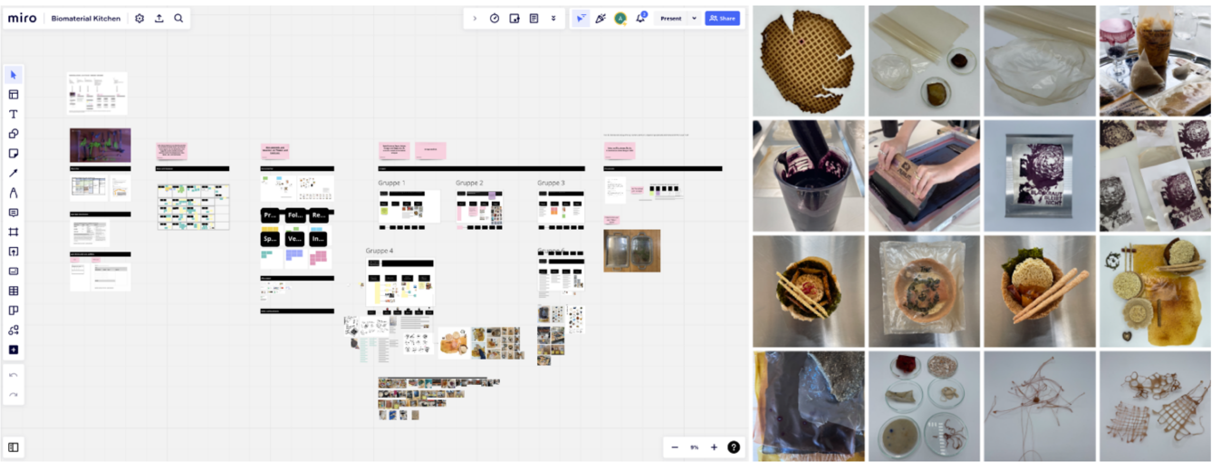
8. l: Process pictures from paste extrusion 3D printing. r: Paste extrusion 3D printer Procusini from Print-to-Taste in action.



9. Biomaterial laboratory equipment and process details for pouring biomaterial films.

3.1 April – Start of CIRCE Creative Fellowship

10. Miro board for "Biomaterial Kitchen" course and collage from participants' works.



The process began by developing a concept for a biomaterial course and organizing the necessary materials. The workshop, titled "Biomaterial Kitchen," aimed to provide participants with a comprehensive understanding of biomaterial design and its significance. During the course, participants engaged in the following key aspects:

- **Presentation and introduction:** The course commenced with an introduction to biomaterial design, emphasizing its relevance in today's context.
- **Edible biomaterials:** Participants were instructed to create edible biomaterial foils using agar agar. Collaborative Exploration: Emphasis was placed on collaborative exploration and documentation of various methods to produce biomaterials using food additives and waste. These materials could be either edible or compostable, promoting sustainability.
- **Manufacturing support:** Guidance and support were offered for manufacturing processes, and participants were assisted in finding specific information related to their focus areas.
- **Final presentation:** Students worked on their use cases and studies throughout the course. Support was provided in conceptualizing their final presentations, later discussed at an open table session. Towards the end of the workshop, a wrap-up session allowed for reflection on the previous work and sharing experiences.

3.2 May – Start of research on biomaterial resources

The process commenced with the exploration of biomaterial resources, encompassing the following steps: Clustering and cataloging resources, including gathering information on their properties, availability, potential applications, and processing guidelines.
Working on experiments, such as recycling pulp and stone powder for the "Paste" aspect, as well as experimenting with grass fiber pulp for both "Paste" and "Pour."

11. Cut grass from garden and manufacturing process for biomaterial film.

By attending a mycelium workshop at the Fraunhofer Institute as part of Munich Creative Business Week 2023 mycelium as a material was considered.

12. Impressions from mycelium workshop.

3.3 June – practicing and starting with experiments

The journey extended to crafting edible biomaterial foils tailored for food packaging and formulating an exhibition concept to convey the ideas and use cases to pertinent stakeholders effectively.
Exploring intriguing possibilities, attention was turned to the biomaterials' potential afterlife, envisioning scenarios like their transformation into "vegan bacon" when combined with vegan barbecue sauce. Parameters were thoughtfully set to maintain research clarity and focus during dedicated weeks.

A precise framework was established to define the primary raw materials for the biomaterial composites. The selected residual materials encompass sawdust from wood, cacao pod fiber, limestone powder, biochar, and cherrystone pod powder. In parallel, waste materials with compostable properties, notably cellulose-based materials such as used eggshell cartons, paper, and various packaging materials, were identified for potential recycling into biomaterials.

13. Cooking fried vegan bacon process.

3.4 July – Deep dive into daily practice and iterative development process

Within this month, the process entered a phase of intensive daily practice and iterative development. It was subdivided into topics, each dedicated to specific aspects of the exploration.

Several significant challenges were encountered throughout the process. These challenges had a substantial impact on the project's development and results. One of the most pressing challenges was managing water content and mitigating shrinkage during drying. Since most biomaterial formulations contained water, drying them presented difficulties. Formulations and 3D-printing constructions were optimized and tested by iterative steps to minimize and control shrinkage to overcome this challenge.

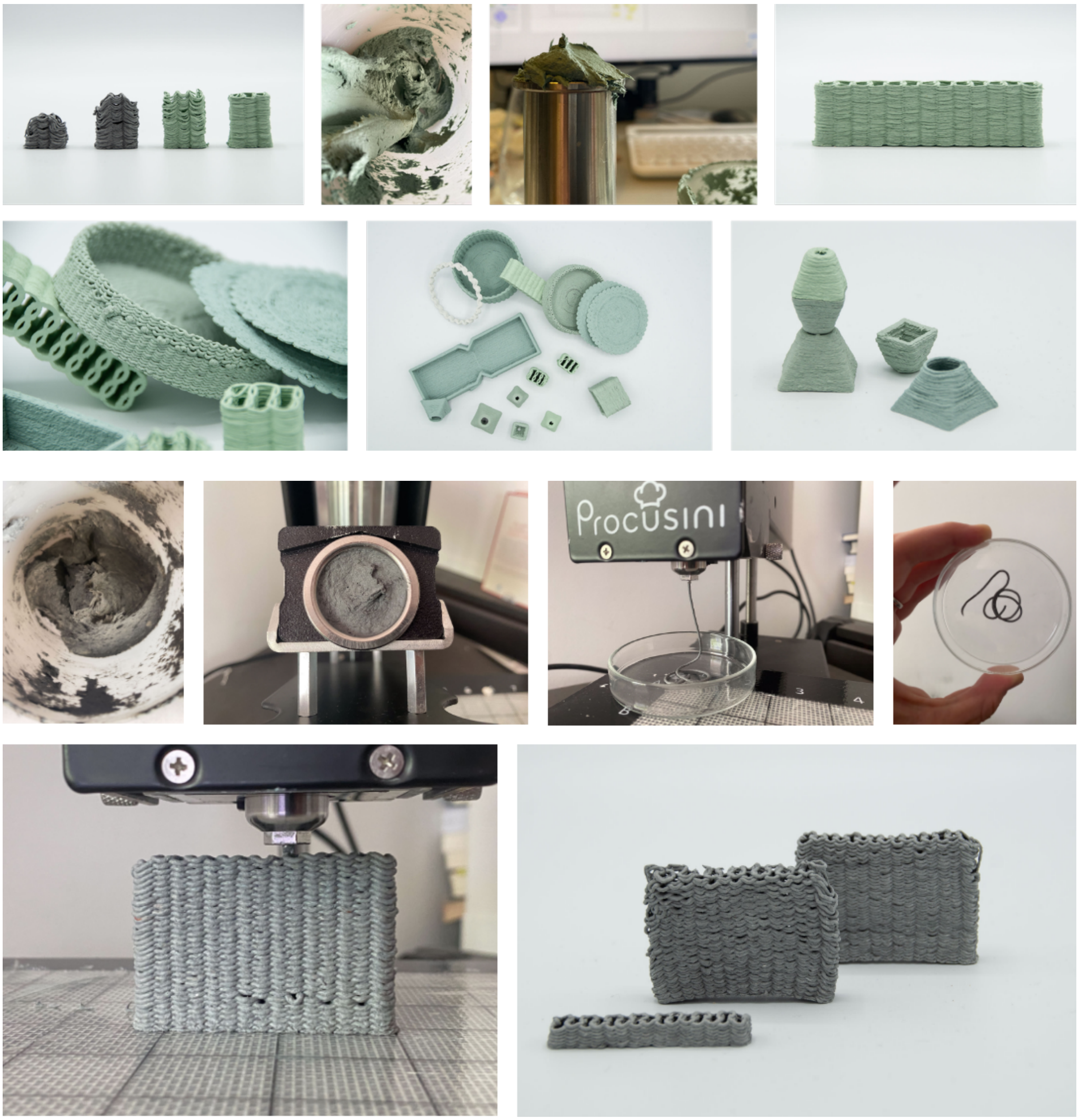
14. Challenging water content for paste extrusion 3D printing.

Another challenge was effectively binding sawdust from wood for paste extrusion 3D-printing and incorporating cherrystone powder into a biomaterial formulation. Finding optimal solutions that work with the 3D-printing paste technique was crucial to ensure cohesion and structural integrity. This required considering the unique properties of the materials. Manipulating the 3D printer code to control the printer's path and optimize the properties of the printed results was also a significant challenge. Precise control over the 3D-printing process was necessary to tailor the biomaterial composites to specific applications. This challenge required a deep understanding of 3D design and code modification to fine-tune the printing parameters for best outcomes.

15. 3D printed structure.

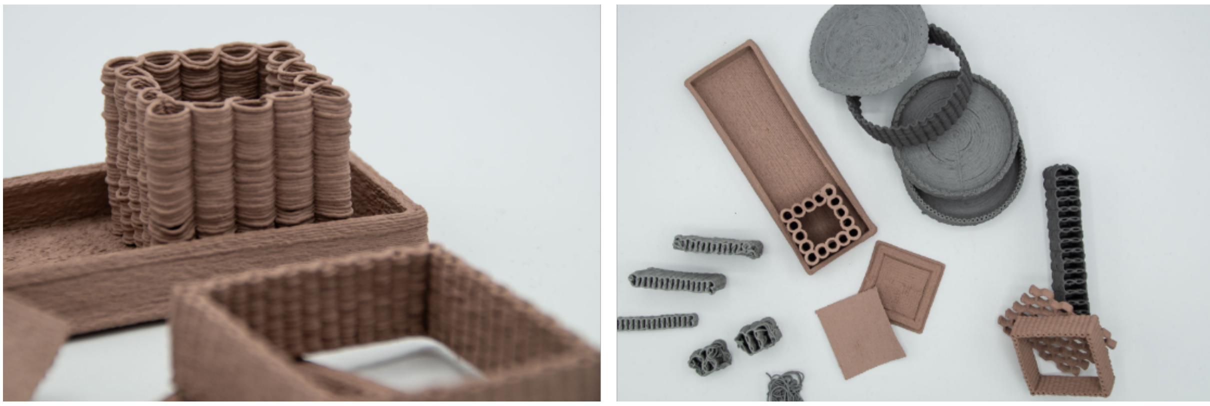
3.4.1 Developing 3D - printable structures for paste extrusion 3d printer (procusini)

16. Collage from developing 3D printing structures.



In this phase, ideas were generated and translated into tangible structures and objects using Rhinoceros 3D. Generated designs were converted into Gcodes, and specialized pastes were prepared for 3D printing. The Procusini 3D printer was configured for optimal performance, and the printing process was closely observed to gain insights. Continuous refinement of design in Rhinoceros 3D and enhancements to slicer settings and Gcode followed. This iterative process was thoroughly documented, capturing construction details, settings, code, timeframes, volumes, evaluations, and improvements.

17. 3D printing structures.



3.4.2 Testing out binder qualities of food additives and their properties for Paste and Pour

This section was focused on evaluating the binding qualities of various food additives and their suitability for both the Paste and Pour techniques. It encompassed precise ingredient preparation and measurement documentation, expert mixing or cooking, and rigorous testing of binding qualities in combination with specific main ingredients: stone powder, cherrystone powder, cacao pod fiber, biochar, and sawdust.

- **Testing viscosity and suitability for Paste and Pour**

This subsegment involved molding paste through injection techniques and utilizing the Pour technique to create foil-based materials. The suitability of different drying methods, including air drying and oven drying, was scrutinized.

- **Repeating and improving compositions**

Given the iterative nature of the development process, biomaterial compositions were repeatedly revisited and improved.

3.4.3 Combining biomaterial compositions and technology/techniques for Paste

18. Process pictures from developing paste extrusion 3D printing doughs and objects.

The fusion of biomaterial compositions with relevant technology and techniques, specifically focusing on Paste, was explored during this topic.

- **Preparing printing objects from the first focus week**

Objects conceptualized during the initial focus week were readied and further developed for experimentation.

- **Preparing doughs for paste (paste extrusion 3D printing)**

Customized doughs tailored for paste extrusion 3D printing were meticulously crafted, incorporating various ingredients, such as sawdust, cacao pod fiber, carbon black, cherrystone powder, and limestone powder.

- **Preparing printer, settings, and nozzle sizes for specific composites**

The 3D printer underwent meticulous configuration, encompassing settings and nozzle sizes optimized for specific biomaterial composites.

- **Watching the printing process and documenting the behavior of combinations (material property and printing qualities)**

The printing process was continuously monitored to assess the behavior of material combinations, focusing on material properties and printing qualities.

- **Drying options (air and oven)**

Air and oven drying were tested, and validated.

- **Results – Stability, strength, flexibility**

The results of these experiments underwent strict validation, evaluating stability, strength, and flexibility.

- **Improving biomaterial composition, 3d construction, and printing settings (code)**

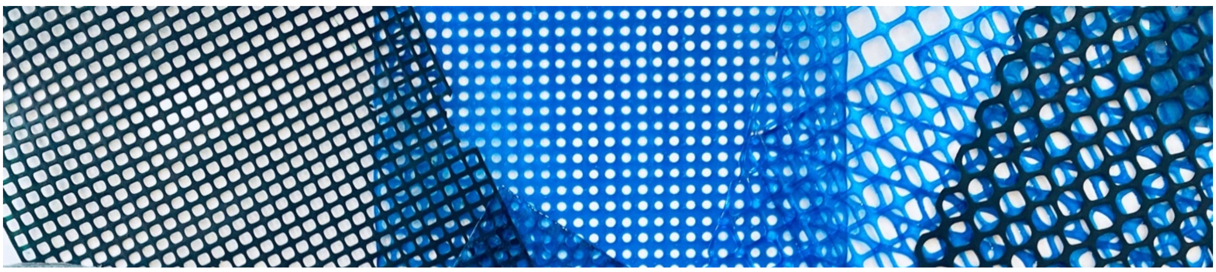
The development process encompassed ongoing enhancements spanning biomaterial composition, 3D construction, and printing settings (code).

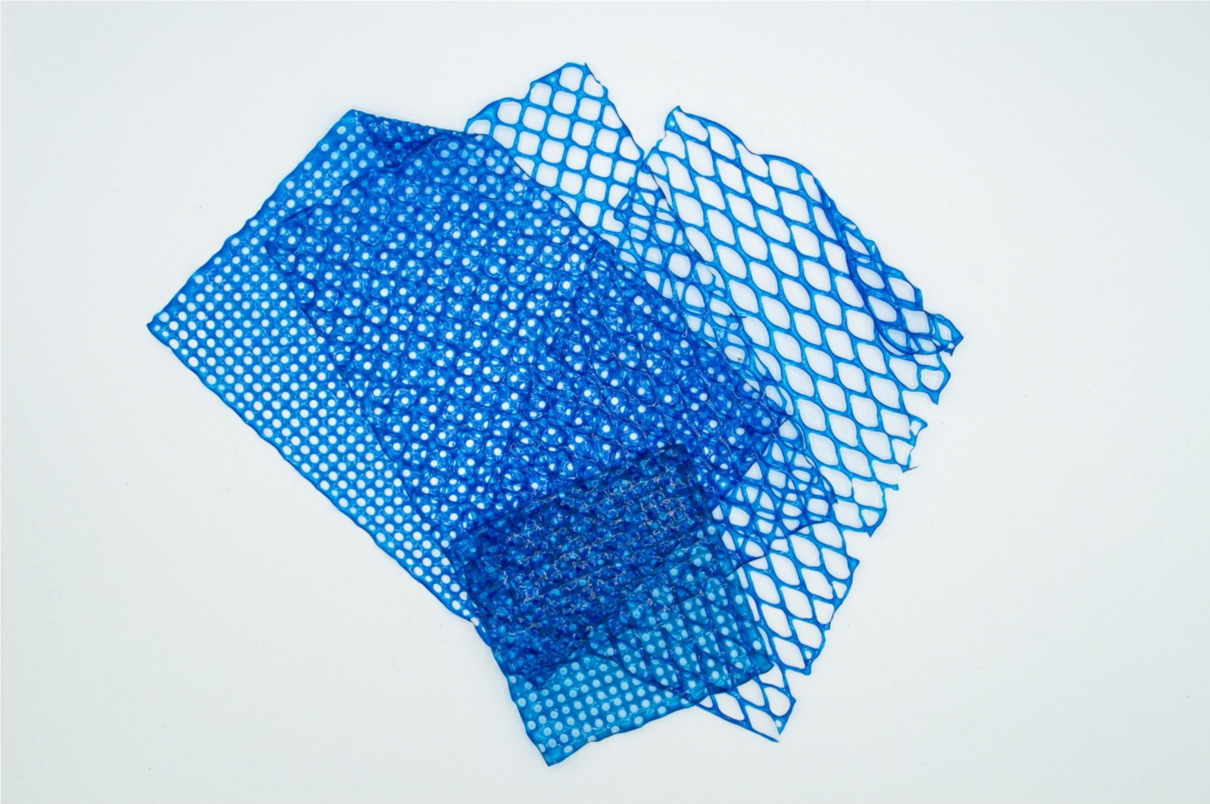
- **Repeating**

The iterative nature of this phase necessitated repeated cycles to refine and optimize biomaterial compositions and printing techniques.

3.4.4 Combining biomaterial composition and techniques to generate textile-like surfaces

19. 3D printed textiles like films.





This section focused on the synergy between biomaterial composition and technology/techniques, merging Pour and Paste to create textile-like surfaces and structures. Two categories explored were algae-based and cellulose-based composites. Each composite was meticulously assessed for suitability in achieving the desired textile-like qualities. Designs were crafted using Rhinoceros 3D to construct 3D structures that form the foundation for textile-like surfaces.

3.5 August – Reflection on process and context

In August, the project entered a phase of contemplation and contextualization, seeking to establish a harmonious connection between theoretical insights and practical application.
During this time, the project tackled previous obstacles and aimed to improve its results significantly. This included systematically utilizing the knowledge and skills obtained in earlier stages. The main goal was to develop further and optimize stone powder composites to balance strength and a slight amount of flexibility.
Furthermore, August witnessed a transformation in the composites' evolution, transcending initial obstacles to attain exceptional results. This progress was particularly evident in the successful development of sawdust composites. Using stone workshop dust, thus reducing waste generation, represented a significant milestone. The entire process was meticulously documented by capturing visual records, ensuring a comprehensive understanding of the outcomes.

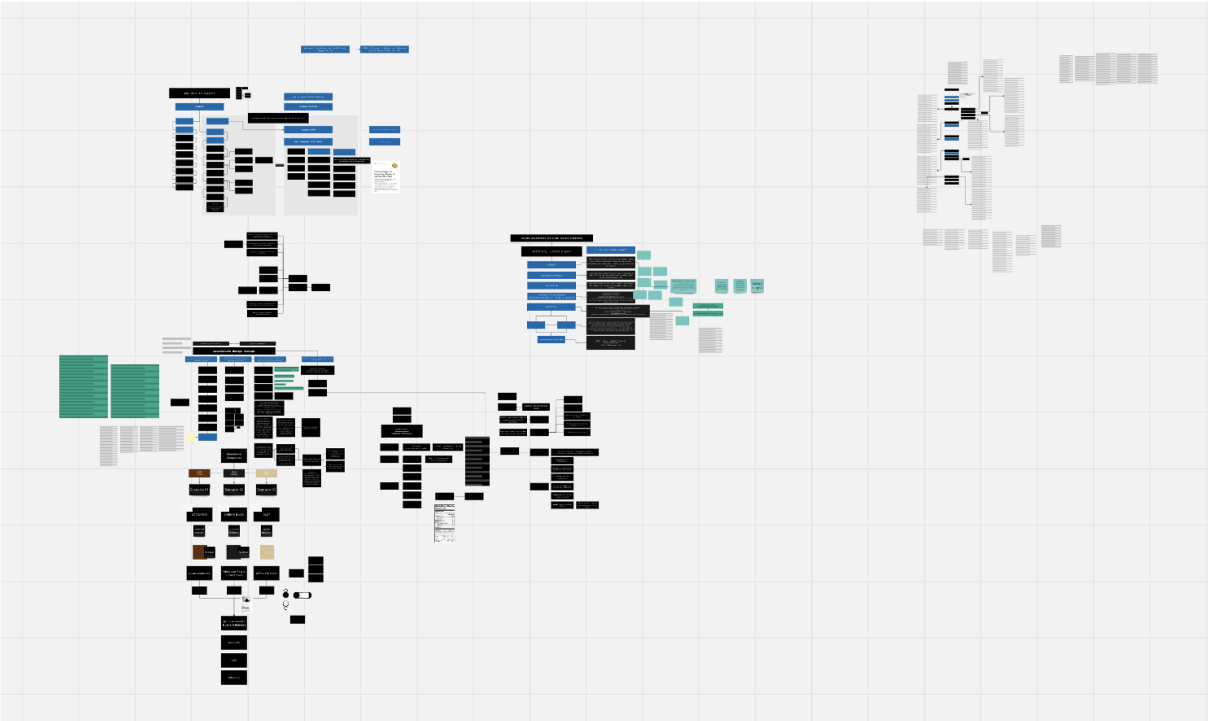
Focusing on Paste

The Pour technique facilitates the production of bioplastic films and surfaces that mimic textiles. Notably, it can be executed using standard commercial kitchen equipment, making it accessible for home-based biomaterial creation. This low-tech approach is versatile and user-friendly.
In contrast, the Paste technique involves 3D printing through paste extrusion, necessitating advanced hardware and software. A local start-up, Print-to-Taste, provides an optimized paste extrusion 3D printer for edible doughs. This technology holds immense promise, particularly in food production, with the potential for large-scale expansion. However, scaling up processed bioplastic foils presents challenges, as evidenced by collaborations with a bioplastic start-up, and the University of Hof's Institute of Biopolymers. The development and validation of each formulation demands an extensive network, diverse expertise, and financial resources.
While paste extrusion 3D printing is still an emerging technology, its integration with digitalization offers scalability for decentralized on-demand production and incorporation into large-scale factory operations. Unlike Fused Deposition Modeling (FDM) 3D printing, which requires filament production beforehand, paste extrusion technology inherently supports scalable production processes. It is an accessible, cost-effective technology ready for integration and scaling.

Considering these factors, the Mattering project leans toward 3D printing formulations over the Pour technique. Paste extrusion 3D printing, with its higher potential, early positive impact, and lower associated risks, aligns well with the goals of the project fostering innovation and sustainability.
In the closing stages of August, the project dedicated time to reflection, replication, and the conclusion of the developmental journey. Reproduction of the sawdust composite was executed to ensure consistency in results. Extensive consideration encompassed all aspects of the project, including the processes, experiences, outcomes, and the prudent allocation of resources. The insights and lessons from this period were summarized meticulously, contributing to the journaling process. Additionally, an effort was made to visualize the broader context within which the outcomes of the project and resource utilization operated, further enhancing comprehension and clarity.

3.6 September – Conception

20. Mind-map screenshot from contextualization and conception process.



The project's culmination has yielded a collection of developed biomaterial composites suited for integration into manufacturing processes, focused on paste extrusion 3D printing. These biomaterials stand ready for use. However, their potential extends beyond immediate application; it embraces a broader perspective, transforming the projects' results into a transformative concept.

The overarching question now explores how these biomaterials could seamlessly integrate into standard production processes, encompassing industry and craft sectors. Moreover, this integration should generate tangible benefits for many stakeholders. The aim is to catalyze transformative pathways towards optimistic future scenarios, offering a way out of manifold crises.

Each biomaterial concept crafted throughout the project represents a narrative for a circular bio-economy. These thought models delve into the biomaterial implementation, inspired by their core ingredients, such as stone powder, cherrystone powder, cacao pod fiber, biochar, or sawdust.

4 RESPONDING MATTER AND RESULTS

Agriculture and food production waste materials and residuals are valuable resources. While some are often overlooked and have no specific purpose, others, like cacao pod fiber, can be used as tea or fertilizer. Unfortunately, the industry tends to ignore the potential of most residuals due to their focus on use cases for specific products and the cheaper cost of fossil-based resources. However, during resource crises, exploring the possibilities of leftovers and utilizing technologies like 3D printing can lead to new business opportunities, increased competitiveness, and support for a sustainable future.

4.1 The combination of materials and technology produces emergent properties

The Paste process offers the possibility to produce strong objects by utilizing geometrical construction and the printer's path. The properties the biomaterial dough gets in combination with this manufacturing process are unique compared to, for example, highly scalable pulp processes or Pour. Some of this project's developed 3D printing structures showcase these emergent properties, like a multiple-weaved cylindric pod. The same biomaterial breaks very quickly with other constructions, but with this, it seems to be unbreakable. Further, the biomaterial qualities can be manipulated by variations of its ingredients. The same ingredients can produce a film or 3D-printed objects. Biochar formulations demonstrate this argument. It is just a matter of quantity and technique. Therefore, many different qualities of the same biomaterial can be produced and offer innovative solutions.

4.2 Quality range and experience of matter

Biomaterials offer unique sensory experience that goes beyond traditional materials. The following dimensions have been considered:

- **Tactile Exploration:** Biomaterials often have unique textures and properties that can be touched and handled to understand their physical characteristics. For example, the smoothness of an edible bioplastic film or the roughness of a composite material made from 3D-printed wood fibers.
- **Visual Appreciation:** Biomaterials can be visually captivating. Their colors, translucency, or opaqueness can be admired, mainly when used in artistic or design applications. Observing how they interact with light and shadow adds an extra dimension to the experience.
- **Aroma and Taste:** Edible biomaterials engage the senses of smell and taste. They can be smelled to understand their aroma and tasted to experience their flavor. This sensory experience is crucial in the development of biomaterials for food-related applications.
- **Sound and Acoustics:** Some biomaterials may have unique acoustic properties. For example, biomaterials used in architectural applications can affect how sound is transmitted, providing a unique auditory experience in spaces constructed with these materials.
- **Environmental Considerations:** Biomaterials often come with an environmental narrative. They communicate information about the material resource they come from in its final form. Knowing that material is sustainable and made from renewable resources can provide a sense of connection to the natural world and a positive environmental impact. Using biomaterials in everyday life, such as furniture, clothing, or packaging, allows individuals to experience sustainability practically. This can foster a sense of responsibility towards the environment.

In conclusion, experiencing biomaterials is an immersive journey that engages multiple senses and dimensions, offering a unique intellectual and emotional experience. Whether through art, design, or sustainable living, biomaterials can revolutionize how we interact with materials and the world around us.

4.3 "Nutrient Materials" are for an "Interim Use of Matter" and for "Eat After Use"

When considering the process, it becomes clear that agricultural and food production waste has great potential when combined with Paste. It is essential to say that none of the used biomaterial resources can be the only one to replace harmful ones. However, they could be part of a "biomaterial turn" and a natural circular material diversity. It is made to experience and to become nutrient soil.

Biomaterial composites necessitate a blend of ingredients, each complying with food-grade or compostable standards to support material circularity. A fundamental principle governing these biomaterial ingredients is their nutritional value and biobased sources. The mission to "Eat after use" encapsulates this approach. It signifies an "inclusive concept of matter" centered on metabolisms and the circularity of materials. "Eat after use" indicates that the material is edible to living organisms, not only humans but also microbes and microorganisms, supporting metabolisms and regeneration. Therefore, using the term "Nutrient Material" (Nu-Ma) instead of "biomaterial" more accurately describes the formulations developed in this project. When standing alone, each of the main ingredients from the developments can act as fertilizer and is compostable. Their use in materials can be called an "interim use of matter"; after its use, the ingredients are to be composted and can act as fertilizer. So, they become nutrient compost, supporting the growth of new raw materials, soil and field regeneration, and a circular economy.

21. Biomaterial film example for: "Eat after use".

22. Sawdust example for: "Eat after use".

The following sections describe the final developments of the project, which offer a new range of material aesthetics and a specific transformative power. A new kind of material experience conveys meaning through integration and reflects unleashed possibilities.

4.3.1 Nu-Ma Stone for Paste

23. Nu-Ma Stone samples.

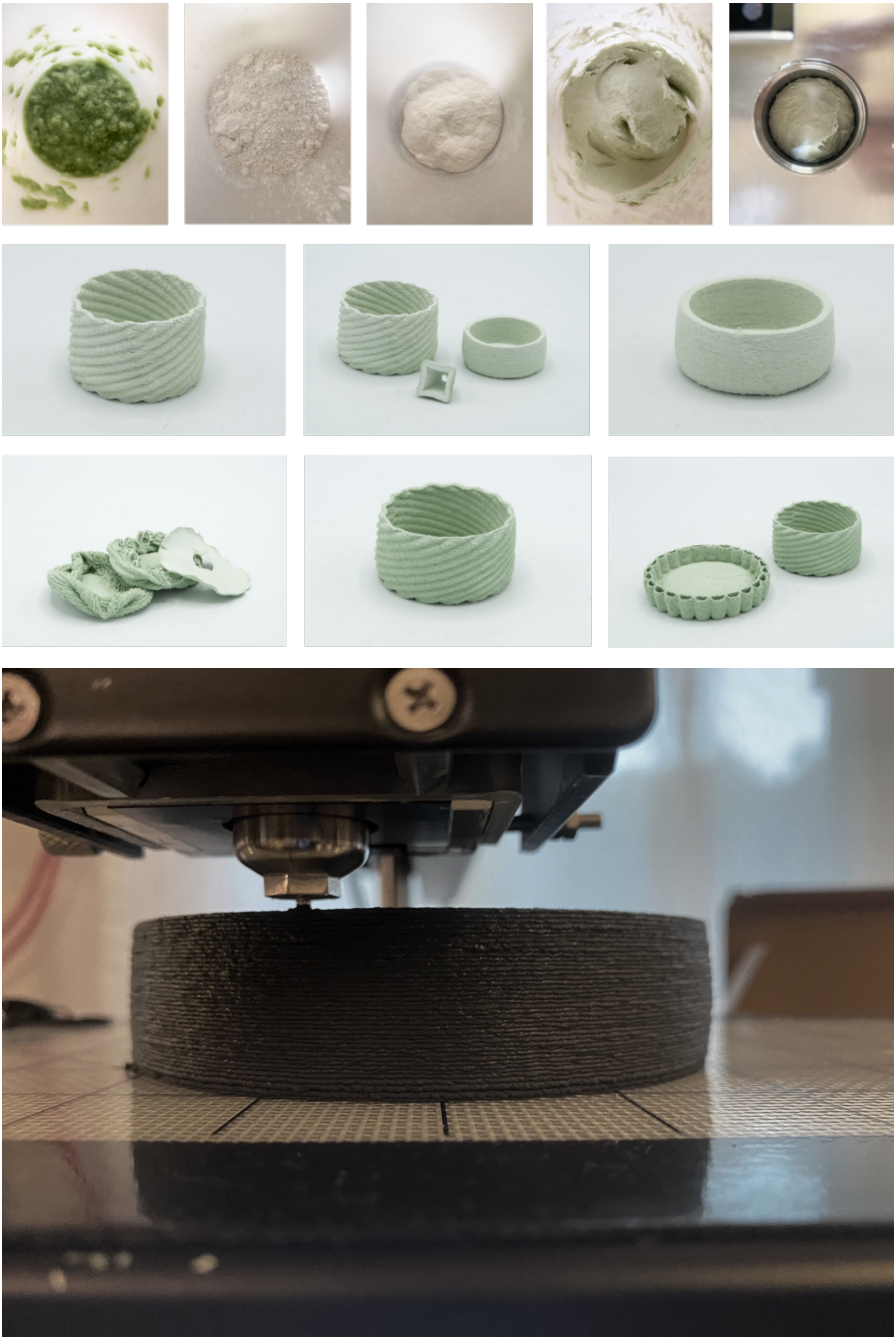
Nu-Ma Stone, made from residuals from quarries, characterized by its soft and white color palette, derives its creamy hues from recycled fibers within its composition. This biomaterial offers a tactile experience defined by its smooth and gentle touch reminiscent of ceramic surfaces. In terms of optics, it presents a visual appearance akin to ceramics.

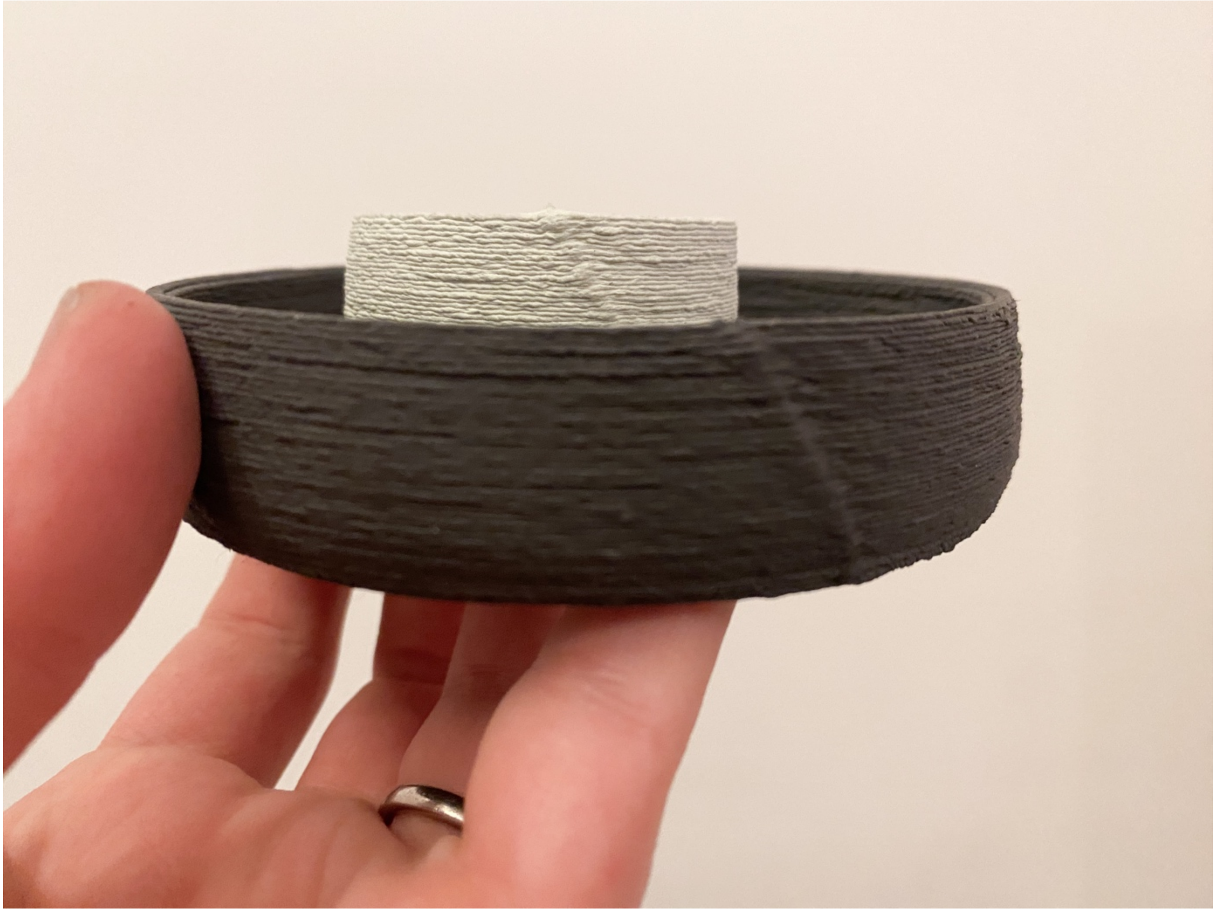
Beyond its visual and tactile appeal, the Nu-Ma Stone boasts flexibility and durability, rendering it nearly unbreakable even in demanding applications. Remarkably, it maintains a neutral fragrance, ensuring it does not overpower its surroundings.

The ingredients of this biomaterial, primarily composed of calcium carbonate, have diverse applications, including serving as a vital food additive for humans and animals. Moreover, pure calcium carbonate is utilized as a fertilizer to nurture soils and as a microorganism nourishing component.

Once the ingredients roles for ceramic-like objects or architectural elements like stucco conclude, stone powder and fibers effortlessly return to their natural cycle, contributing to the nourishment of microorganisms and animals. This circularity underscores its alignment with sustainable practices and environmental stewardship.

24. Nu-Ma Stone manufacturing process and samples.





4.3.2 Nu-Ma Cherrystone for Paste

25. Nu-Ma Cherrystone samples.

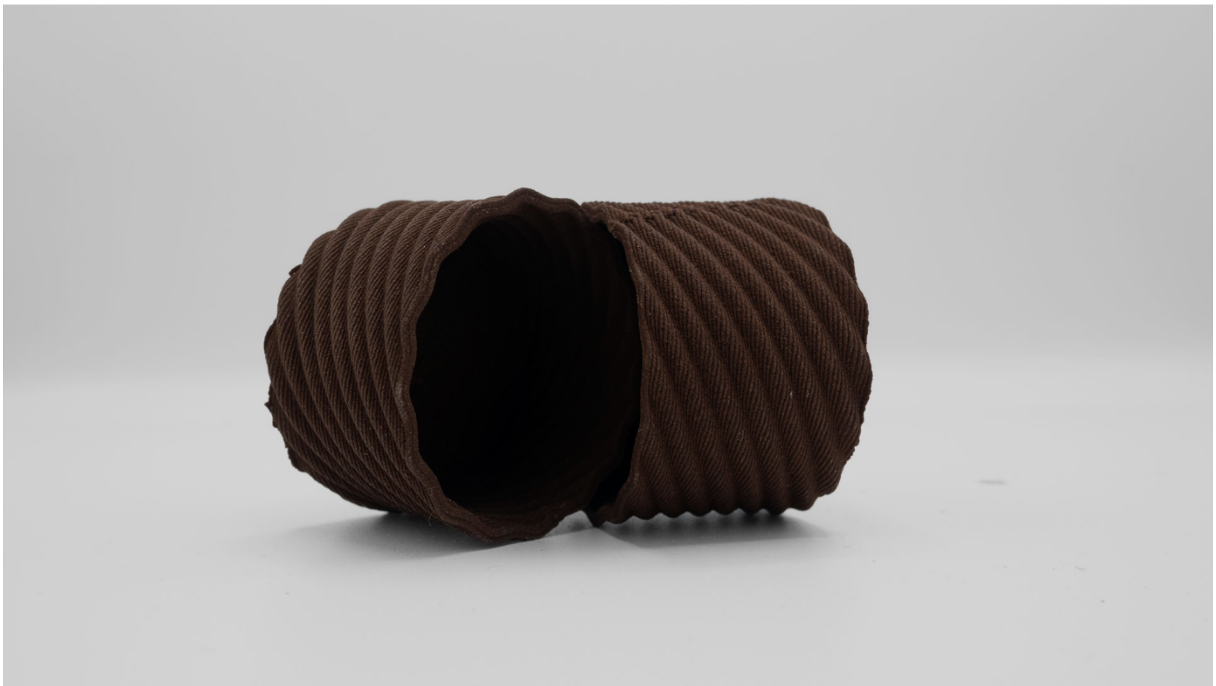
This cherrystone pod powder-based biomaterial boasts an intense beige color reminiscent of its origin, the cherrystones. This color can be modified, becoming lighter and softer with the addition of stone powder. Its composition presents a granulated texture, evoking the natural feel of stone fragments. When touched, it offers a robust and rough tactile experience, reflecting its durability. One of its most distinctive attributes is the strong and invigorating scent of cherries that it emits.

Originating as a residual material from food production, particularly cherry juice processing, cherrystones have found applications, such as creating pillows and cosmetics. The formulation of Nu-Ma Cherrystone as a biomaterial opens doors to more valuable and consumable items, including packaging, desk or table accessories, and potentially even larger-scale objects like furniture and architectural elements when employed with larger paste extrusion 3D printers. This versatility makes Nu-Ma Cherrystone a valuable contributor to sustainable design and circular practices.

26. Nu-Ma Cherrystone developing process and samples.

4.3.3 Nu-Ma Cacao for Paste

27. Nu-Ma Cacao samples with strong structure.



The Nu-Ma Cacao formulation made from cacao pod fibers and food additives possesses distinct characteristics that provide a sensory and tactile experience reminiscent of its origin. It imparts a warm and inviting sensation upon contact, combining softness with inherent durability. Its deep brown hue strikingly resembles a piece of dark chocolate, establishing a visual link to its cacao heritage.

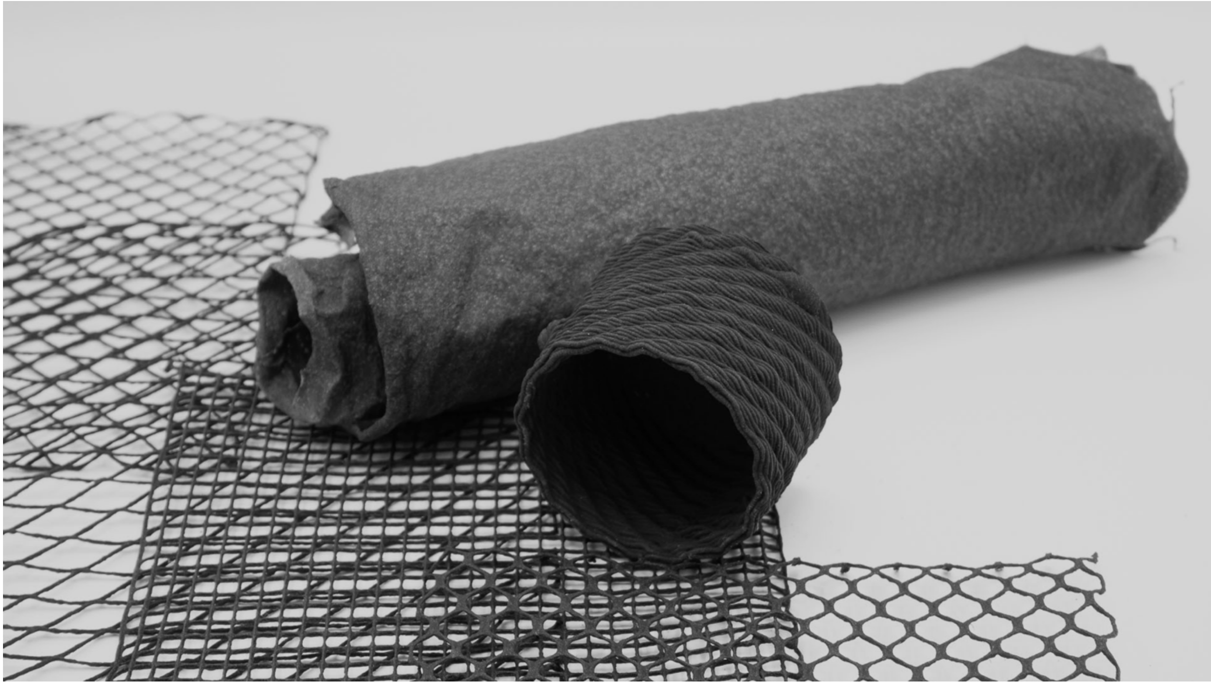
A highlight of this composite material is its potent cacao aroma, which envelops its surroundings with the irresistible scent of chocolate. Engaging with this Nutrient Material in a cup can intensify experiences like participating in a chocolate ceremony. In this journey, the senses are heightened, and emotions stirred, fostering a profound connection with the essence of cacao.

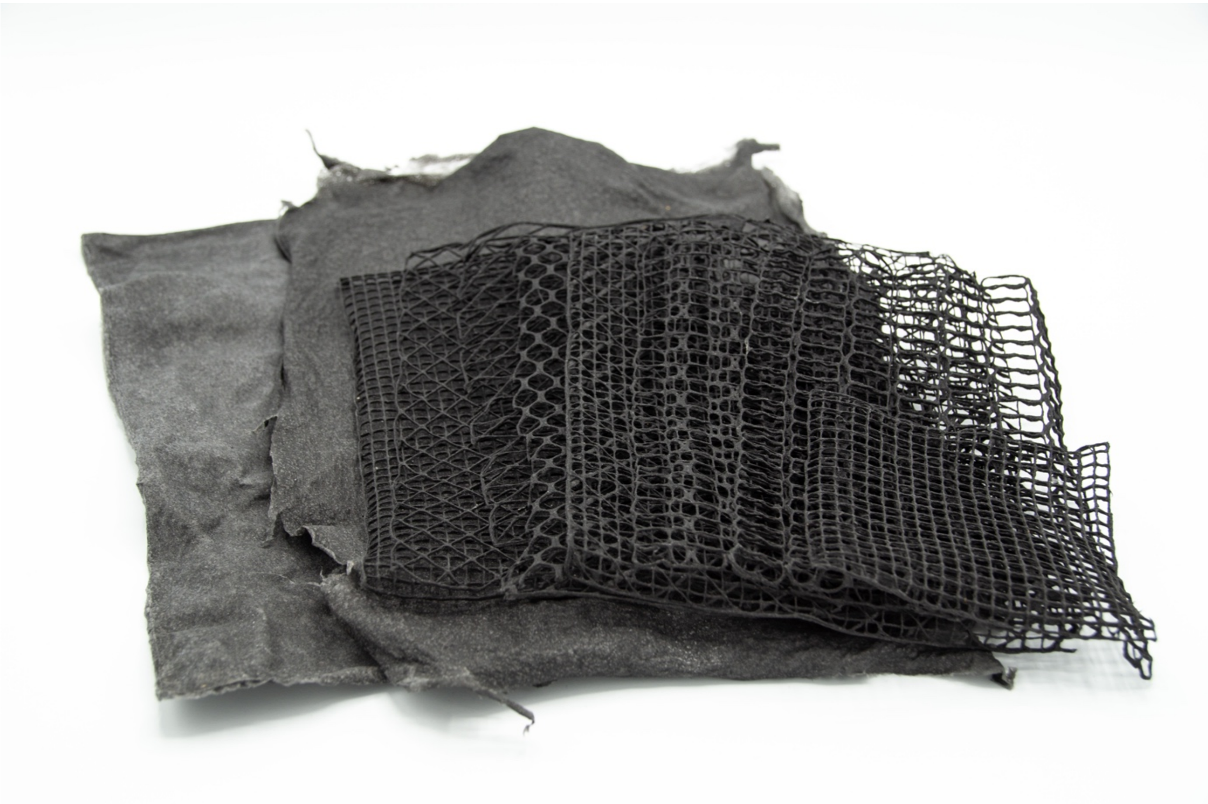
Furthermore, the potential applications of cacao pod biomass extend to innovative business ventures, including creating edible cacao cups and unique 3D-printed cacao-themed packaging designs. This biomaterial originates from cacao production residual and closes the loop as it progresses through its lifecycle. Once its primary role concludes, it gracefully transitions into composting. Its nutrient-rich components circulate within the living ecosystem, nurturing renewable resources and facilitating sustainable growth.

28. Nu-Ma Cacao developing process and samples.

4.3.4 Nu-Ma Carbon Black for Paste and Pour

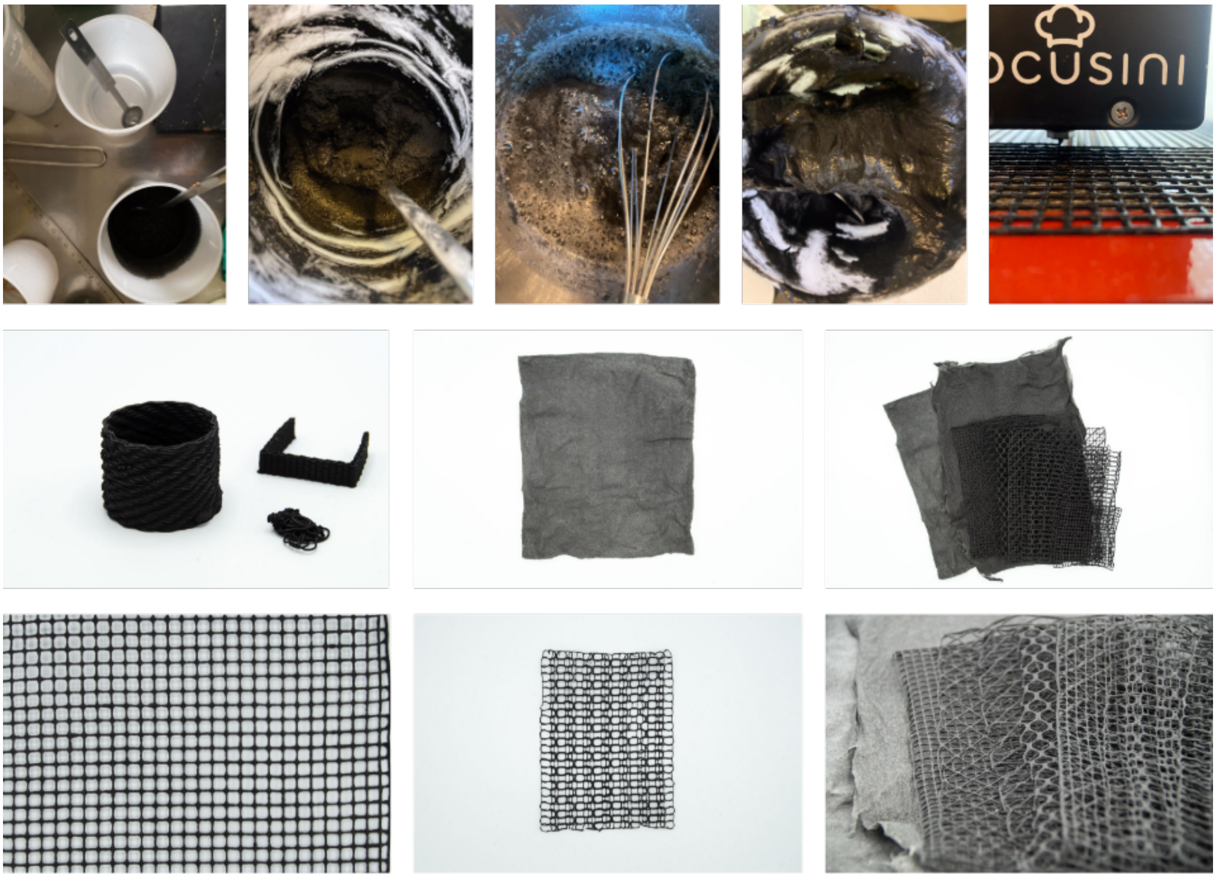
29. Nu-Ma Carbon Black samples. Poured film, 3D printed meshes, and 3D printed strong structure.





Transformed by the addition of a natural food-grade binder, biochar evolves into a deep black 3D printing paste with a distinct visual allure. Its texture combines slight roughness with flexibility, offering a tactile experience that balances strength and suppleness. Remarkably, it is totally odor neutral.
The versatility of this biomaterial extends to environmental applications. It can also utilize the remnants of events like forest fires for 3D printing. After fulfilling its role in a 3D printed product, it transitions into a plant fertilizer, fostering nature's regeneration. Its profound black aesthetic potential makes it an excellent choice for charcoal pencils packaging. Manufacturers of artist pens can make packaging from their own leftovers. Post-use, it can either fuel further artistic creations or contribute to composting, embodying the circularity of materials and environmental sustainability.

30. Nu-Ma Carbon Black developing process and samples.



4.3.5 Nu-Ma Sawdust for Paste

31. Nu-Ma Sawdust samples.

Nu-Ma Sawdust is a biomaterial composite with food additive binder, fibers, and limestone powder. Its wood particles define its outer structure, and its color, which blends with creamy white tones, possesses a distinct visual appeal. Its surface, displaying a clear cream-white hue, invites touch with its remarkably smooth texture. The biomaterial offers a unique combination of flexibility and strength, delivering a tactile experience that aligns with its natural origins. The included fibers have the potential for sound-absorbing panels used in architecture.

Moreover, the biomaterial captures the essence of wood in its aroma, evoking the pleasant scent of the forest. Traditionally, sawdust has been utilized to create wooden furniture surfaces, pressed into panels, and finished with artificial substances to achieve desired properties. However, this method is typically reserved for larger-scale manufacturing and unsuited for smaller woodwork workshops. The sawdust formulation introduces a simplified, more circular approach to working with this abundant material. It enables crafting individual accessories and furniture items, harnessing sawdust's innate qualities. Notably, after fulfilling its initial purpose, the biomaterial ingredients seamlessly reintegrate into the natural material cycle, supporting the growth of new trees and contributing to sustainability efforts.

32. Nu-Ma Sawdust developing process and samples.

5 AN EMPOWERMENT OF MATTER

The insights gleaned from the Mattering Project have significant implications for addressing the overarching questions posed by CIRCE and understanding the role of cultural and creative economies in contemporary and future crises. They offer valuable conclusions for shaping the trajectory of the economies in Europe, and they may resonate with other CIRCE projects, with potential implications for policymaking.

Sustainable biomaterials as catalysts for transformation

The project's exploration of sustainable biomaterials showcases the potential for innovative materials to drive transformative change within cultural and creative economies. Using renewable resources and byproducts, biomaterials offer a sustainable alternative to traditional materials. This can reduce environmental impact and resource consumption, aligning with the broader European sustainability agenda. The project demonstrates how creative sectors can play a pivotal role in sustainable practices and contribute to a more circular and regenerative economy.

Interdisciplinary collaboration

The Mattering Project emphasizes the necessity of interdisciplinary collaboration. Success in developing biomaterials for creative purposes requires expertise in materials science, design, and art. This highlights the importance of fostering collaborations across traditionally separate fields. Such interdisciplinary approaches can serve as a model for addressing complex challenges in the cultural and creative sectors, including those brought about by crises.

Scaling innovation for resilience

The insights emphasize the importance of scalability for innovative solutions. While some techniques, like 3D printing with biomaterials, are nascent, they hold promise for scalable production. This scalability is essential for resilience, as it allows for decentralized on-demand manufacturing and can be leveraged in responding to crises such as supply chain disruptions. Scaling up creative and cultural innovations can enhance the sector's adaptability in a rapidly changing world.

Circularity and biomaterials

The project's focus on biomaterials and their circularity reflects broader trends in Europe's push toward a circular bio-economy. Biomaterials, by their very nature, support circular principles. They can be created, used, and returned to the ecosystem as nutrients, contributing to soil regeneration and sustainable agricultural practices. This aligns with the EU's Circular Economy Action Plan, which seeks to minimize waste and promote resource efficiency.

Implications for other CIRCE projects

These insights may resonate with other CIRCE projects exploring sustainability, circularity, and innovation within the cultural and creative economies. The learnings from the Mattering project could inform and inspire similar initiatives, fostering a network of projects collectively contributing to the transformation of these sectors.

Policy implications

Policymakers should take note of the potential of biomaterials and sustainable practices within the cultural and creative sectors. Support for interdisciplinary research, innovation hubs, and scaling initiatives can accelerate the adoption of sustainable biomaterials. Moreover, creating an enabling environment encouraging experimentation and risk-taking is crucial for fostering innovation in these sectors.

In conclusion, the Mattering project's insights offer a glimpse into the future of European cultural and creative economies. They reveal the potential for these sectors to lead in sustainability, circularity, and interdisciplinary collaboration. By embracing biomaterials and scalable innovation, Europe's cultural and creative economies can contribute significantly to a resilient, regenerative, and environmentally responsible future. These insights can benefit the creative industries and serve as a model for sustainable practices across various sectors, aligning with the broader goals of Europe's transition to a circular economy.

6 INDEX

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