Processes, Fabrication and Design with Kombucha Bacterial Cellulose: Mapping Practices

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Abstract

Kombucha is a fermented drink that has been drunk in Asia for centuries and has recently been popularized in Western cultures. The production of the beverage generates a co-product, a biofilm of Bacterial Cellulose (BC). This biofilm is today at the center of a typology of bio-design practices, ranging from initiation workshops to fermentation to practical and plastic research around shaping objects with this living matter. This paper proposes an overview and initial classification of the current design practices that use Kombucha Bacterial Cellulose as the raw material for artifacts. To this extent, we structured a corpus of selected projects in a Principal Component Analysis (PCA) map. We classified 38 projects in the field of design made between 1985 to 2022. Each project is positioned in an orthonormal frame of reference according to its degree of definition of use (from the most unrestricted use to the most defined use) and its scale of manufacture (from single experimentation to industrial production). This map tries to bridge the gap between the communities.

Keywords

Kombucha, Bio-design, Cartography, Mapping, Bacterial Cellulose.

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Introduction

Current sustainability contexts highlight the collaborative relationships between humans and living organisms. Small and growing organisms feed us and produce the raw materials needed to make everyday objects. Kombucha can do both at the same time. The nature of their two-fold production can be seen either as the produce or the co-produce. While working with raw materials such as wood (cellulose) to create furniture or domestic objects, designers and makers have recently used the (macro) co-produce of living symbiotic (micro) organisms. Among these, the co-produce of Kombucha has been used to create objects and artifacts.

Kombucha beverages contain a bacteria and yeast symbiotic culture that grows in a sweet tea solution. This association between organisms results in a natural fermentation process that transforms the sweet tea solution into a solution with nutraceutical properties.

One particularity of Kombucha is that acetobacter makes a biofilm or strain of bacterial cellulose on top of the beverage. Many communities share strains and form a human-sharing network of kombucha mothers for personal use.

At a macro scale, this Bacterial Cellulose (BC) is a raw material that designers can treat and process. In recent years, Kombucha products and co-product have been of interest to many research and design practitioners. They offer a simple and robust living medium for experimenting with living things, even in a DIY or domestic setting and urban spaces. More generally, we use the term biofabricated materials to describe the materials using living organisms in their production (microbes rather than plants or animals).

The science of "Kombucha" as Bacterial Cellulose (BC) is usually segmented into more or less scattered fields: biology [1] , medicine [2], food [3] , textiles [4] , and material science [5]. This ensemble draws a vast potential for use and practice, which are only sometimes put in parallel, and remain most often exclusive. However, it needs to be determined how the materiality of this research influences design choices and how the designer's communities can mobilize them for developing and employing the best strategies in producing artifacts.

To tackle this issue, we propose an initial mapping that organizes these heterogeneous BC-based designs and research domains that elaborate an emerging form of possible new materiality. To build this map, we rely on 38 prior works that their authors classify as "art" or "design" pieces. We focus on works that use either Bacterial Cellulose as raw material or demonstrate the growth process. This collection reflects the applicative or demonstrative potential of working with living materials.

Our mapping questions and challenges the possible symbiotic relationships between non-humans and humans. Addressing these assemblages through Design offers a practical and mobilizable prism of applied bacterial cellulose's state of the art.

A new take on Symbiotic Design with the Living

Designing and fabricating new materials or objects using living organisms' natural processes of growth or reproduction is a secular process rooted in the human desire for control over nature. Traditionally, this process is entrenched in arts and craft fabrication. Artisans can understand raw materials and grow, select, or shape them according to their knowledge of the processes, creating a collaborative and synergetic process. "*Making is to growing as being to becoming*" [6] ; the technical transformation of living materials implies nurturing and cultivation: "*if things grow, they are also grown*" [7]. This creation is beneficial from a design perspective, as it creates the serendipity necessary to emerge new shapes and forms. Other practitioners are engaged in this discipline. This paper will refer to the users involved in active collaboration with the living to produce goods as "*producers*." We identified this process as performed by several people, including Artisans, Designers, or Makers.

This collaborative process has slowly been forgotten over the past decades or taken over by mass-manufactured petroleum-based products. The rise of sustainability challenges has raised questions about designing in collaboration with the living and using the co-product of already used processes, and are at challenges at several scales. On the one hand, at a large or macro scale, it is often hard for the producer to control the form of the object [8]. It involves operation at different stages of the organism's life cycle that allows shapes or final designs to emerge. On the other hand, the fabrication processes can be controlled at a small or microscale but are challenging for producers.

The design community used growing materials such as Mycelium or Bacterial Cellulose as emerging material practice [9], leading to the Growing Design movement exploring the emergence of artifacts. Produces use the materiality of the medium to support the creation of

artifacts. It is mainly the case for Mycelium, which allows the creation of composite bio-materials capable of mechanically structuring the object [10].

Bacterial Cellulose provides other opportunities. These biological systems can assemble biodegradable and conformable complex structures that can self-repair, sense, and respond to external stimuli. Bacterial Cellulose is the product of sugar synthesis by acetic acid bacteria —– the interaction with yeast and other types of bacteria in SCOBY will not be discussed here. The Bacterial Cellulose grows on the surface of a sweet tea liquid aerobically, encouraged by the exchange interface between air and the fluid. The overall appearance of fresh (i.e., wet) bacterial Cellulose is slimy. Once dried, it is similar to paper or leather. The latter state is most often used as raw material for production in textile design. In addition to being able to be processed artisanally (using leather work, sewing), this state is more prone to speculative and experiential uses — they seek to provoke a question or emotional design through touch, sight, or smell (sour).

The works, pieces, and projects made within the community use different fabrication processes and design methods and target different audiences. While they offer a wide range of variability and diversity, it can be challenging for designers or makers to understand how the field is structured and how he or they can intervene. Thus, our proposed mapping offers a global overview and a practical perspective to the still-growing community of bio designers.

From Design Projects to Classification

Corpus selection

Based on our observation of the kombucha producers — a community in which we take part—we estimate that artists and designers have produced around a couple of thousand design projects with kombucha. To create this map, we decided to select representative artifacts that showcase the main capabilities of the material. Our choice rationale was first to pick projects identified by their creators as "art," "design," "piece," "objects," or "garment/cloth/textile."

The prism of practice and production was the second selection criterion. This method excluded most of the theoretical biology and engineering research projects, drink, and the more known derivatives of the BC. Furthermore, the projects without direct objective implications in instruments or artifacts were not kept. Furthermore, in the cases of projects with similar process, outcome, and look, we opt to merge various projects with one representative visible one.

In this collection, we deliberately exclude aestheticism classification as the reception of works that produce objects with living matter oscillates between fascination and disgust— even fear (contamination, slimy, etc.).

Among this list, the projects ranged from social design to product design. Both are between the "doing" and the more or less driven user prescription. The list of selected projects in our map can be seen in the **Bibliography** section**.**

Methodology and Visual Representation

The main objective of the visual representation is to summarize the information in this heterogeneous corpus. The second objective is to provide a broad, flexible grid of analysis that highlights, at the same time, links and differences and provide a visualization tool to understand the variety of use of BC that open up design potentials.

There are several ways to classify and discriminate the selected works. The choice of factors is motivated by the desire to characterize the design practices through the spectrum of the objects produced and their relative fabrication processes.

We used a two-factor classification, used in the design project and methodologies. The first factor was to consider the use and the user, while the second was to evaluate the production scale. It allows us to visualize the main benefit of BC on a 2-axis graph.

The horizontal axis represents the production scale. The spectrum ranges from manufacturing —closer to art, experimental, or artisanal practice—to industrial production. The axis highlights on one side the uniqueness of the lived experience and the questions raised by observing, experiencing, or interacting with the artifact, while highlighting the standardization and scale while informing the piece's replicability level on the other side.

The vertical axis represents the orientation of selected production in relation to practice and use, that is, the spectrum from passive contemplation to complex use defined in a restricted field. Its scope ranges from experimental use to defined (prescribed?) use. The top part of the axis values the material quality corresponding to the need, while the bottom describes

more artistic and experimental practices where the goal isn't oriented on the quality but on the experience for the spectator or public.

Each selected project was given by the authors two 0-10 grades on the factors: the fabrication quality and the design prescription. This grade was used to position the project on the 2D axis. It should be noted that we display superimposed works in adjacency for visual representation. After placing the papers on the grid, the authors extracted clusters of domains.

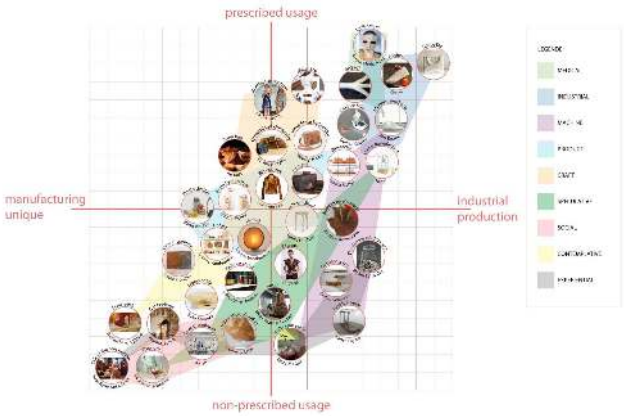

Figure 1. Processes, Fabrication and Design with Kombucha Bacterial Cellulose: Mapping Practices.

Mapping Bacterial Cellulose Design Practices

The Mapping is represented in Figure 1. The 2D axis mapping is divided into four square spaces, with points spatially representing the projects. Each point is visually represented by a bubble containing an image and surrounded by its title and main authors. The points (bubble) are joined in clusters by distinct colored frames referring to domains: medical, industrial, machine, product, craft, speculative, social, contemplative, experiential.

Spatial Representation

The general location of the projects draws a diagonal from the lower left to the upper right part. The typologies of the projects selected can explain this. There is a constant progression between the level of prescription of the use of the BC towards the user simultaneously as the complexity of technical manufacture increases. Thus, the diagonal represents the increase in the complexity of the functions of the artifacts.

The upper left and lower right parts contain fewer project bubbles than the other spaces. The upper left and lower right half are mainly empty in our representation. However, some projects could be representative. An example from the top left could be the use of BC kombucha for food production, thus reversing the notion of product/co-product in the industry (cellulose paste as an additive, for instance, for sauces or ice cream). However, these uses are separate from current design practices, as we need representative examples of the industrial production of a food product as artistic or design production. Thus, this upper left corner is empty because there is hardly any object that is both mainly prescribed and, at the same time, exceptionally technically unspecified.

Similarly, the lower right corner is also empty because this space represents artifacts that would be industrially very advanced (machine and other complex implementations needed for production) yet have very little prescribed use or even a demonstrative or speculative use. On the one hand, this map area should be occupied by standardized products resulting from a complex industrial process, waiting for a noble valorization use —other than composting or methanation, for example. Products of this type may not be design projects, but industrial co-products and have been excluded from our corpus. On the other hand, while the realization of a machine or a process is often driven by the creation of a specific and precise object, we can cite the works of Bianca Hlywa [11] or Stephan Schwabe [12] that deepen the technical fabrication process for artistic purposes with the BC.

Clusters: Domains of Interest for Design

The different clusters refer to different domains. The Medical cluster gathers projects developed for medical use, from cutting-edge research to marketed bandages [13]. The Industrial cluster gathers projects developed by industrial actors from an industrial perspective. The Machine cluster gathers projects oriented to the machine that allows the growing process, like bioreactor —more than the result of the growing process. Conversely, the Product cluster cares for these growing results and gathers objects made with BC. The Craft cluster is oriented to artisanal knowledge. The Speculative cluster gathers projects related to speculative art or speculative design, meaning their operating function is intended to develop critical thinking. The Social cluster gathers projects that are collective experiences and social forms related to Social Design and Relational Æsthetics.[14] The Contemplative cluster gathers mostly art projects that aim to provide

an æsthetic experience (primarily oriented to visual sense). The Experiential cluster gathers projects that offer multi-sense experiential expertise.

From the position of the projects, we defined and distinct nine overlapping clusters that characterize the type of practices with BC. Each represents a different domain of design that is mainly explored with BC. While not exhaustive, this list allows the viewer or user of the map to position other works not present in the current map.

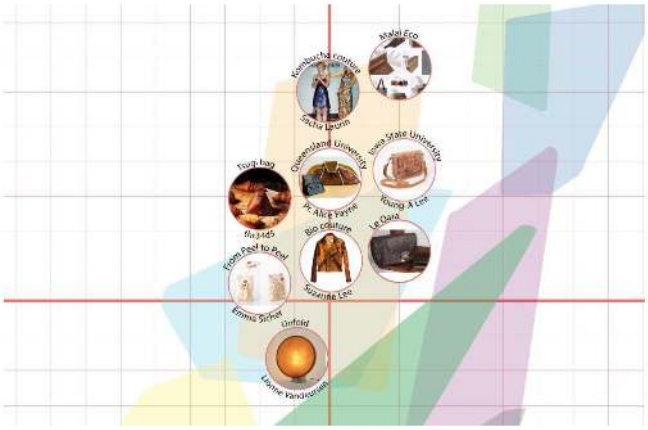

Figure 2. Division by clusters. Here the projects in the Craft category are highlighted.

Some projects are linked to several fields. As an example, in the "Craft" category (Figure 2), *Malai.eco*[15] is a company that grows BC from coconut to make leather products—as *Kombucha Couture,*[16] but with a larger scale and with a real industrial methodology. They grow BC in bio lab conditions and produce BC by the meter to use this finished piece as material for sewing bags, shoes, etc. We defined Kombucha Couture as an artisanal production in comparison to Biocoute. Artists such as Suzanne Lee,[17] who initiated the engagement in design for BC and Biocouture, maintain the craft relationship to production.

Overall, other overlapping communities have been revealed in our mapping. For instance, the Medical cluster is porous with other practices because practitioners develop incredibly defined projects with very robust and rigorous uses and technical production methods. On the opposite side, the Speculative, Social, Contemplative, and Experiential clusters share most of their points because it is challenging to define the boundaries of their respective projects. Their positions are less linked to the type of production than to the engagement sought by their creator with the spectator, the user.

Limitations of the Mapping

This article provides an initial classification of design projects utilizing Kombucha as a base material. With this map, we contribute to a better understanding of the possibilities and enlarge the scope of existing projects.

This cartography is a tentative way to structure the artwork from our observation and reflect our opinion that is open to discussion and debate within the community. We acknowledge some limitations of our mapping. The classification, according to the position, simplifies the positioning of the selected project and offers a look and a perspective on a very heterogeneous taxonomy. The selection criteria are related to projects which can show a new potential use of the fabrication process for BC. Or, we sometimes select one work to best figure for a tiny cluster of practices, or we pick the most popular and referent work as seen by the community. Although some projects could have been included, the artifacts resulting from biology papers did not have direct "objective" implications in the instrument of production and are not seen as design artifacts by their creators and not mobilizing enough by the designers. In an attempt to overcome this limitation, we created an updatable interactive map[18] that provides flexible classification choices. The interactive map also allows us to easily integrate proposals from the community.

Similarly, some objects/artifacts/instruments were difficult to categorize strictly into a field. Often, the possibility of classifying the objects in two dimensions facilitates decision-making. Most often, the gap and similarities between the project types define the position of the object in the frame. Thus, it is a look at the whole production and their characteristics in relation to each other that positions the projects in a more comprehensive and coherent view.

Conclusion: Statement about the Importance of Kombucha based Design Practices

New Forms for Design: Slow Growth Monitoring

The design practices of Kombucha BC can be applied to the challenges of today's world. With our dependence on energy, it is important to come up with solutions that are local and meaningful. Choosing to work with living organisms to maximize production is a skill that humanity has mastered. With the help of (bio)technologies, we are able to have greater control over the production of living things, leading to new ways of creating materials through programming or simulation.

However, the process is slow and challenges our understanding of resources, their availability and arrangement.

Our map shows that monitoring biological activity is crucial in redefining how we use living things. We can use scientific measurement methodologies and bioengineering tools such as thermal imaging, graphs and optimization techniques to control, analyze and adapt our productions at a slow rate of growth. Monitoring is an essential part of all the projects presented, providing expertise and control to producers, enabling them to anticipate production or even design without material. This reinforces the sociotechnical regimes through design, linking human beings and non-humans through machine mediums.

Emerging Role of Process engineering

The impact of digital manufacturing tools and DIY chemical processes on design has now been followed by the impact of biology and synthetic biology tools and processes.[19] To design and manufacture with living organisms, Process Engineering is crucial. By understanding the biology of living organisms, producers can interact with and mobilize them in production.[20] This understanding allows producers to access dedicated tools and engineering technologies of production that redefine the relationship with emerging things. These technologies include programming living matter (modification of the environment or genetic reprogramming) and programming material behaviors (4D printing, programmable matter, structures with auxetic behaviors, soft-robotics, digital fluid mechanics, etc.).

Our analysis of the corpus shows that these technologies arise from a design valorization of bioengineering methods combined with DIY fabrication tools.[21] The combination of living organisms within production machines challenges the link between parasitism and symbiosis, resulting in machine-organic producers of "bio-artifacts."

Evolving Role of the Designer

This practice can profoundly transform our relationship with living materials that can now be easily shaped and transformed in a DIY. Beyond the design with non-human living forms, the fusion between materials science and synthetic biology is playing out at a new crossroads of ecology that is neither scientific nor animistic. Working with the living has existed since the dawn of humanity. The rise of these processes can be seen as a renewal or update in manufacturing and design thanks to the knowledge of the biological matter.

Working with biological processes also questions designers' intention to collaborate with living matter to repair their practices. They can seek to improve the link between everyday objects and the modern world we live in, because they could be partly responsible for this unsustainable environment.

While incomplete, we hope this map will foster discussion and generate new ideas in the design community. More generally, we argue that Design with Kombucha Bacterial Cellulose is a way to connect and re-contextualize the modern (bio)technological convergence through æsthetics and design.

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