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Cooking Objects: Bio-Digital Material Driven Design Methodology

Tomás Vivanco Larrain
Pontificia Universidad Católica de Chile | Chile | tvivancol@uc.cl

Tongji University | China |

Philip Yuan
Tongji University | China | philipyuan007@tongji.edu.cn

Abstract

This article presents a Biomaterial Design Methodology based on the idea that common people can produce objects using bio-based ingredients to create biomaterials and digital fabrication technologies as tools to drive the design processes. The emergence of biomaterials open-source recipes in maker communities and digital fabrication laboratories open new approaches for design, raising the idea that designers can become cookers, controlling all design process and its potential outcomes. The methodology presents four steps to develop recipes and biomaterials to achieve a final product design without requiring any previous knowledge. Also combines different digital fabrication techniques to produce new material expressions, systems, functionalities and products.

Keywords: Biomaterials, Material Driven-Design, Bio-Digital Fabrication, Cooking Objects, Material Computation

INTRODUCTION

High gastronomy arrived in daily life through cooking recipes distributed in notebooks and cooking books. The act of cooking a recipe means to follow a defined procedure and methodology using specific ingredients and tools. However, following all the steps with care does not warranty the achievement of the original dish.

By repeating the preparation of the same recipe several times, the cooker will take control of the process and gradually will modify it considering his technique, tools and local ingredients. When there is absolute control of the process, the cooker will be able to repeat the process producing the same outcome, which will not suffer considerable differences. By achieving this, a new recipe be created, a variation of the original that cannot be claimed by any other cooker.

The proliferation of digital fabrication machines, and the exponential growth of digital fabrication laboratories around the world, build the premise of democratizing production. By giving ordinary people access to tools for design and fabricate (almost) anything (Gershenfeld, 2005). A second turn has been made, this time around sustainability, local materials and bio-fabrication (Stein, 2017) as cross axes that feed the digital production and products design processes.

CONTEXT

Industrialized design and manufacturing processes address the mass production of goods without establishing any interactive relationship between the creator and the user. The worldwide consolidated maker movement supported by smart, flexible and low production factories as Fab Lab and Maker Spaces are changing this counter interaction between creators and users through the unification of specific and individual necessities with production processes. At the same time, creators without design or engineering background who share their creations in open communities using open source and creative commons protocols might be able to produce their own products, but with a low industrial resolution. Materials and machining processes with basic expertise in design production, common in these creative contexts, helps to the emergence of a non-industrialized finishing, offering novel aesthetics in product design.

Fab Labs and Maker Spaces offer the capacity to produce (almost) anything to any person. However, because of the same lack of expertise in product design, the use of digital tools and material processes, final results often present a low-quality resolution compared with industrial products. For this reason, these spaces should incorporate to a `how to finish (almost) anything` processes in order to create final products that could be closer to users' expectations. Nevertheless, the main focus of these spaces is to promote processes, knowledge and a responsible and sustainable culture for consumption and production (Walter-Herrmann and Büching, 2013) rather than products. Nevertheless, one of the critical points in makers networks practices is the use of sustainable materials (Kohtala, 2016) that can ensure good product quality and at the same time can contribute to a circular system within these networks.

The general idea that a 3d printer can produce free shapes under certain restrictions triggered the question of how sustainable these processes are and how digital fabrication tools can be integrated in the broader view of our society, industry and environment, linked with the circular economy (Diez, et al, 2018).

Designing in the Anthropocene era entails the use of critical and speculative methods (Anderson, 2015) to explore new ways for applied discussions of the implications of industrial and technological development on our natural environment. In this path, the Do It Yourself movement is not staying behind, by adopting the emergent 'DIY material practice'(Rognoli, Bianchini, Maffei & Karana, 2015). Focused on design and fabrication of materials and products using living organisms or biological-based materials.

The use of biomaterials offers the opportunity of novel esthetics that can express signs of a cultural movement and new tendencies for sustainability in contrast to high energy produced goods through conventional industrialized processes. At the same time, empower makers and designer to control and design all the material production processes (Rognoli et al., 2015) and to create specific material and product performances.

A worldwide abundance of biobased ingredients and component and the accessibility to fabrication laboratories supports the Growing Design practice (Montalti, Ciuffi, 2013). Where common processes and successful recipes are shared in these networks in digital platforms such as Materiom (Garmulerwicz & Corbin) and Fab Textiles (Pistofidou), and physical spaces as open Bio Laboratories. It is generating a collaborative, global and open-source biomaterial network platform that supports the local production of bio-based materials, products and knowledge.

Digital Distribution of material recipes is setting up new spaces of contribution, distribution and retribution between communities in a horizontal and bottom-up direction. BioPlastic Cookbook (Fab Textiles, 2018), Fungus Biofabrication Manual (BioFab UC, 2019), Recipes for Material Activism (Ribul, 2014), among others, offer great support and initial guidance to makers and students to start bio-based design processes. Social networks as Instagram also contributes to the distribution of recipes and bio-products images shared under the tag biofabrication, at the same time, the open-source project sharing platform instructables offer bioplastics recipes tutorials for makers, allowing them to create their own materials. In this last case, the lack of clear protocols and a deeper understanding of material science constraints and properties, both qualitative and quantitative to measure and inform design processes.

It is opening the opportunity to define new interactions between designers(chefs) and users (cookers), digital tools with biomaterials, and costumers with products. Instead of design and manufacturing products, we can move to the idea of cooking objects using recipes supported by global available biomaterials and ingredients.

BIO FABRICATION

The intersection of biology and design can be categorized into four primary material design practices (Carmere, Karana, 2017): Growing Design, Augmented Biology, Digital Fabrication and Biodesign fiction. The purposed methodology of Biomaterial Design can be positioned in the four of them, but more straightly into Growing Design and Bio-Digital Fabrication. Both as the creation of bio components materials can combine them with the use of digital tools for product production.

Growing design is the control of living organ- ism's growth as drivers to the creation of shapes and functional forms. Meaning the use of the power of nature as a co-worker in the design process (Collet, 2009). For example, the growth of a mycelium

the growth of mycelium in a controlled, shaped substrate to create a specific form.

BIODIGITAL FABRICATION

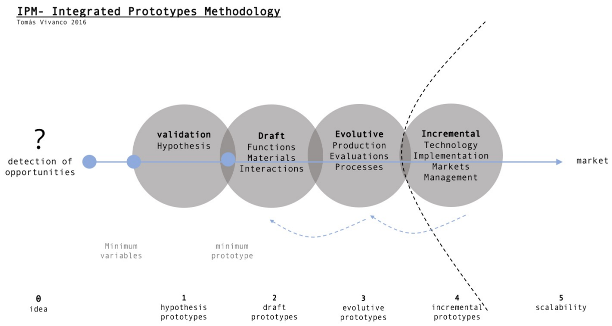
The term BioDigital has been widely used in computational design in approaching design inspired by nature, understanding geometrical systems and virtual growth. In nature, a form is meant to be in a specific way and not something else, they can´t be something else (Vivanco, 2019). Depending on the scale, the structure is given in different forms in natural systems, for example, exoskeletons only exist in nature in a smaller scale in which gravity plays no role as superficial tension does, this means that in the human scale, a beetle will be mashed by its own weight.

Digitally control of a living organism's growth considers this constrains as they work directly with biological matter (Oxman, 2010). Is not the representation of the system, but is the system *per se*. In a growing biological process, digital fabrication is understood as a guide that actively controls form in close dialogue with the organism' properties, principles and development of biological growth.

METHODS AND PROCESSES

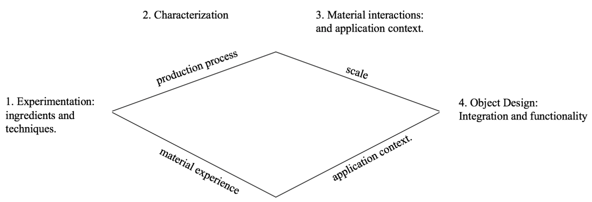
The integration of biomaterial production in a design process requires the comprehension and navigation within a global methodology to achieve a clear outcome, for the process of making biomaterials to produce a functional object using digital fabrication tools, two previously known design methodologies where integrated. The first was the Integrated Prototypes Methodology (Vivanco, 2016). This prototype-based process starts from a scientific hypothesis and its validation, to continue with the development of drafts and evolutive prototypes. Finishing with an incremental functional prototype in a progressive increment of the complexity of each specific goal and step (Figure 1). The second methodology, known as Material Driven Design Methodology (Karana, et. al, 2015), defines four steps to achieve a material- based products. Starting from understanding materials and its characterization, then creating a material experience vision, patterns and concluding with designing a material or product concepts.

Figure 1. Integrated Prototypes Methodology, Vivanco, Tomas. 2016.



After applying both methodologies as enablers and drivers of design and production processes, in previous experiments developed with downloaded recipes, natural integration of both methodologies emerged to specifically work with biomaterials, defined as BioMaterial Driven Design Methodology (Figure 2). Focused on the selection of material ingredients, their impact on material expression and characteristics and the incidence of production processes in the material and product definition.

Figure 2. BioMaterial Driven Design Methodology.



Biomaterial Driven Design is composed of four stages, after defining material or global primary initial hypothesis.

Step 1. Experimentation: In the first stage, each ingredient was considered its contribution to the mechanical performance of the final material, by changing their proportions in the cooking process.

Step 2. Characterization and Material Experience: The material characterization is divided into two analyses, in one hand are the intensive properties of compression, elasticity and stiffness. In the other hand, extensive physical properties where measured. These characterizations are conducted by potential design applications informing digital fabrication strategies.

Step 3. Material Interactions: Envisioning, which is the material application field, is a process informed by data, experience and production processes depending on availability, production volume, scale, tools and equipment. Positioning the material in an inseparable relation of its characterization and production process with its wide application field.

Step 4. Product Design: Each material experience is associated with a specific function that will define the final product. At the same time, the product is also its own reverse engineering process considering ingredients, protocols, extensive properties, digital tools and machines used for the production.

In order to proof and crystalize the exposed context of this research and the developed methodology, recipes number 42 (Kombucha Fabric), 24 (Agar - gelatin plastic) and 22 (Gelatin bioplastic recipes) (Table 1) from Materiom.org were reproduced in the BioFabrication and Digital Fabrication Laboratories, equipped with basic bio-tools and digital fabrication tools. Each recipe was repeated several times until the produced material reached mechanical stability. These materials were subjected to the four stages of the previously defined design and prototyping methodologies.

Table 1. Downloaded recipes from Materiom.org

number	*recepie*	*tools*	*ingredient 1*	*ingredient 2*	*ingredient 3*	*ingredient 4*
42	Kombucha Fabric	Teaspoon, Measuring Cup, Scale,	Grean Tea 55 gr.	Water 1 lt.	Sugar 55 gr.	Sodium Bicarbonate 1 unit
24	Agar - gelatin plastic	Cooker/stove/hotplate, Teaspoon,Measuring Cup, Cooking pot,Thermometer, Stirring spoon	Glycerol 1.5 tablespoon	Water 2 cups	Gelatin 20 grams	Agar Agar 1 tablespoom
22	Gelatin bioplastic	Cooker/stove/hotplate, Teaspoon,Measuring Cup, Cooking pot, Scale,Thermometer	Glycerol 12 gr	Water 240 ml	Gelatin 48 gr	

These characterizations are conducted by potential design applications informing digital fabrication strategies.

APPLICATION OF THE METHODOLOGY. UNDERSTANDING DIGITAL RECIPES.

After downloading biomaterials recipes from digital platforms, two main thoughts immediately emerge after analyzing them. Several predefined ingredients compose the final material; each one of them plays a specific performance or role in the outcome material that is entirely unknown. Also, the measurement units are not unified, increasing the inaccuracy at the very beginning of the process.

These are crucial elements to consider in the application of the methodological procedure for material creation. Because of this, the three recipes were combined in order to have a uniform protocol and control over ingredients. Combining the ingredients requires the follow of specific protocols to control time, temperature and movements, to ensure consistent results that can be replicated.

STEP 1. EXPERIMENTATION: INGREDIENTS AND TECHNIQUES.

As the first stage, each ingredient was evaluated by its contribution to the mechanical performance of the final material by changing their proportions in the cooking process, and as a second step, each ingredient was evaluated concerning its global availability.

The experimentation was conducted to achieve a stable thermodynamic protein the cooking temperature must be stable over 95 ° C, point where the protein structures break conforming a stable organization (Matsuura, et al., 2015).

This allowed to mix ingredients, define specific proportions and establish experimentation techniques for the definition of new recipes (Table 2).

Table 2. Modified recipes.

id	*recepie*	*tools*	*ingredient 1*	*ingredient 2*	*ingredient 3*	*ingredient 4*
A	Scooby bioplastic	Teaspoon, Measuring Cup, Scale,	250 gr. SCCOOBY	50 gr Alginate		
B	Bio Foam	Cooker/stove/hotplate, Teaspoon,Measuring Cup, Cooking pot,Thermometer, Stirring spoon	6 gr. Glycerol	60 ml Water	28 gr. Gelatin	6 gr. Bioshampoo

STEP 2. CHARACTERIZATION PROCESS AND MATERIAL EXPERIENCE.

The material characterization is divided into two analyses, in one hand are the intensive properties of compression, elasticity and stiffness that will inform the mechanical definitions of the material in a performative aspect. In the other hand, extensive physical properties where measured. These characterizations are conducted by potential design applications informing digital production processes decisions.

Depending on the context either professional or maker, material characterization can be both qualitative and quantitative nevertheless, feeling the material properties (Karana, 2015) is an enabler experience for a design process that gradually guide the design decisions (Figure 3).

Figure 3. Experiencing the material properties.

Digital Fabrication techniques and processes play an essential role in order to control, conduct and process the production by defining the scale and performance of the material. In this perspective, the exposed methodology applies Digital Fabrication as a way of controlling the shape of a biological organism as mycelium growth (Figure 4) (Figure 5) and or - as in the case of both previously defined recipes - processing the material as an extrusion (Figure 6) or controlling the material with laser cut molds (Figure 7).

Figure 4. Ostreatus Pleurotus mycelium growth controlled with a laser cutted mold.

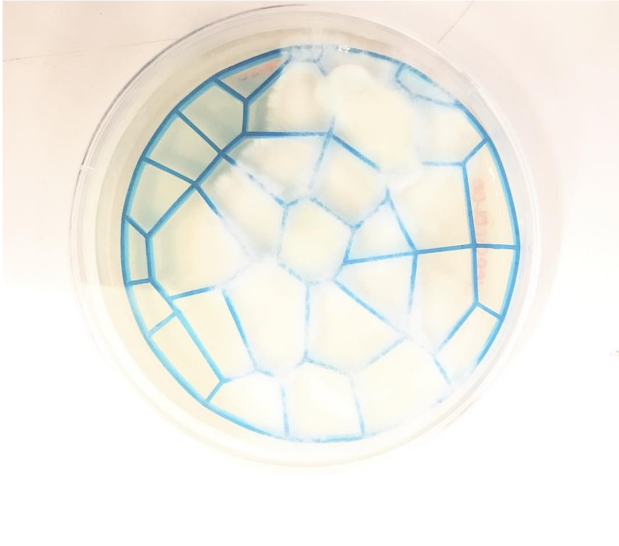


Figure 5. Ostreatus Pleurotus digitally controlled mycelium growth with an actuated substratum.

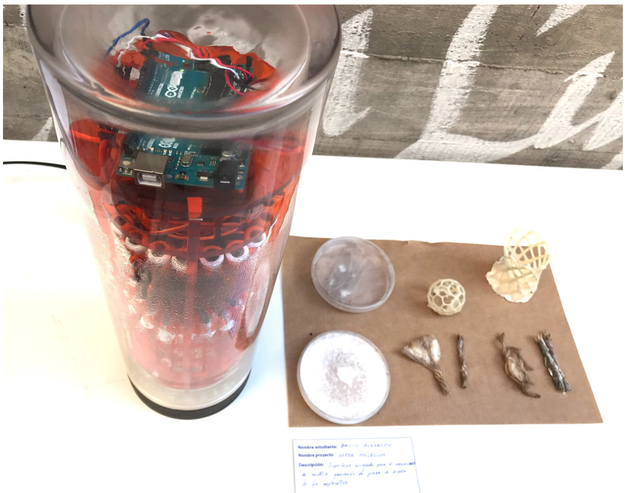


Figure 6. 3d printing extruder with Bacterial Bioplastic (recipe A).

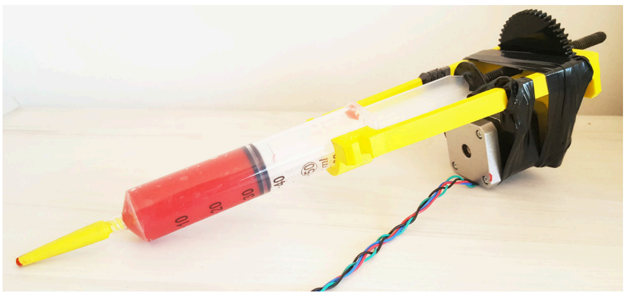


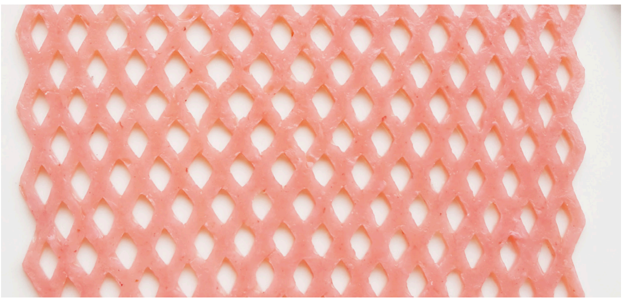
Figure 7. Bioplastic (recipe B) laser cut mold.

A critical issue of this stage is the material stability, depending on the external agents of the environment (humidity, temperature, lux, bacteria contamination, among others) the material will not be exposed to state changes during its production.

STEP 3. MATERIAL INTERACTIONS: SCALE AND APPLICATION CONTEXT.

Envisioning which is could be the material application fields is a process that should be informed by data, experience and production processes depending on availability, production volume, scale, tools and equipment. Positioning the material in an inseparable relation of its characterization and production process (Figure 8) with its wide application field.

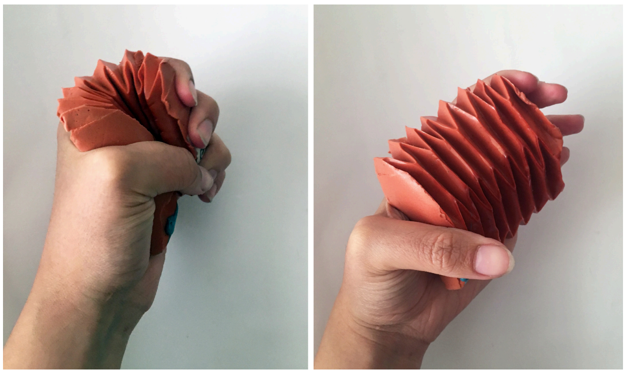
Figure 8. Recipe A, 3d printed lattice.



From this point, materials are fully understood from their extensive properties (Leach, 2017), and they capacities of generating experiences and uses in the mesoscale (Wagensberg, 2004) between material science and design (Ou, et al, 2016).

This means that material properties and scale developed in the specific context of production (eg. Fab Lab, makerspace, BioLab) defines the potential destiny of the application. At this point, the cookers' control over specific production processes and protocols is completely informed by the experimental experiences and data extracted from the material (Figure 9), now understood as a system. This means that through the design process, functionality starts to emerge.

Figure 9. Recipe B, experiencing material compression and flexibility as a system achieved with lacer cut mold.



STEP 4. PRODUCT DESIGN: INTEGRATION AND FUNCTIONALITY.

Each material experience is associated to a specific function that will define the final product. At the same time, the product is also its own reverse engineering process considering ingredients, protocols, extensive properties (to guarantee the successfulness of the recipe process), digital tools and machines used for the production.

By integrating the envision the material potential application field, experimenting with its meta- systems functions and production capacities, the wide functional possibilities are quite limited, constraining the outcome to be more specific (Image 10). In a way, the process defines the will of the material.

Figure 10. Recipe B, Bio Sandal.

CONCLUSIONS

The combination of local biomaterials production with digital fabrication techniques allow the opening of new prospective design processes in the Anthropocene era. This will push the design discipline to develop new ways of production and how to interact with users by empower them to produce their own products in a sustainable way.

A critical point extracted from this research is the tension between the top decision or constrains that the recipe have that might affect the personalization or bottom decisions taken by the producers. Moving slightly away from the stricken protocols might end up with useless results that might be looked as a potential threat in a DIY culture.

The use of a BioMaterial Driven Design Methodology can open new ways of how designers and makers can approach their design, creating sustainable products and question conventional industrial production by changing the idea of manufacturing products to cooking products.

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