# TECHNICAL INTRODUCTION TO BIOMATERIALS

*Materiom*

Reflow

# CHALLENGE

“extraordinary efforts to transform the global plastics economy are needed”

| 23 million metric tons (2016) | ----► | 53 million metric tons (2030) |
|---|---|---|

*plastic waste entering the oceans*

*Borelle et al., (2020), Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution*

# BIOECONOMY

Encompassing the **sustainable production of renewable resources** from land, fisheries and aquaculture environments and their conversion **into food, feed, fiber bio-based products and bio-energy** as well as the related public goods.

*European Commision*

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# BIOECONOMY

Encompassing the **sustainable production of renewable resources** from land, fisheries and aquaculture environments and their conversion **into food, feed, fiber bio-based products and bio-energy** as well as the related public goods.

*European Commision*

***Bio-based plastics***

*Fully or partially made from biological resources, rather than fossil raw materials. They are not necessarily compostable or biodegradable.*

***Biodegradable and compostable plastics***

*Biodegrade in certain conditions, and may be made from fossil-fuel based materials. They can contribute to reducing 'unavoidable' littering, but do not fully solve the littering problem.*

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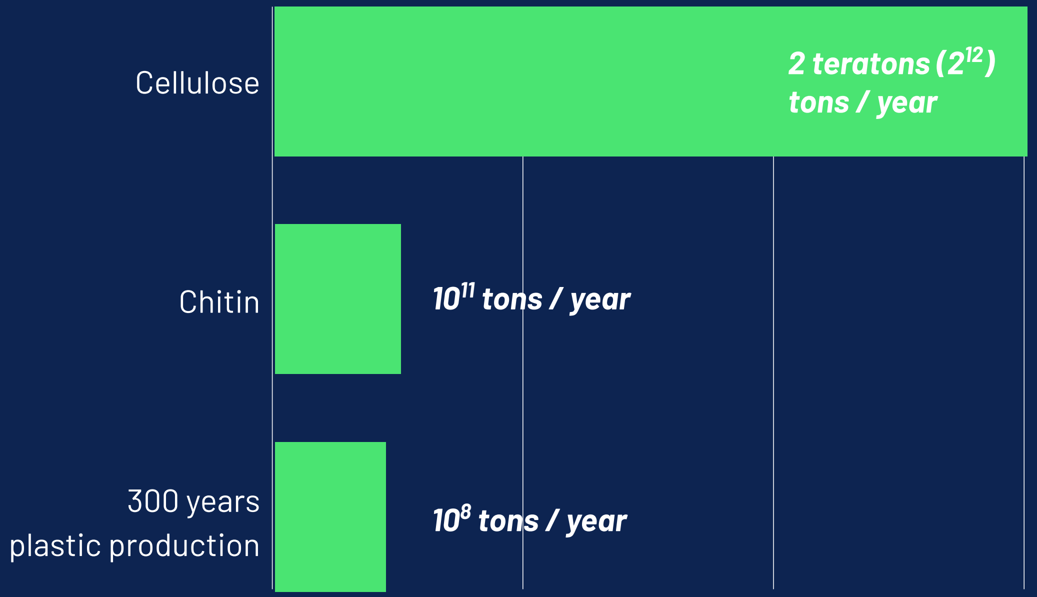
# OPPORTUNITY

## Abundance of biopolymers building blocks per year

*The amount of cellulose and chitin that is produced naturally every year in the environment is far more than 300 years of petrochemical plastic production.*

*What could be learned from our ecosystem?*




*Fernandez & Dritsas (2020), The biomaterial age*

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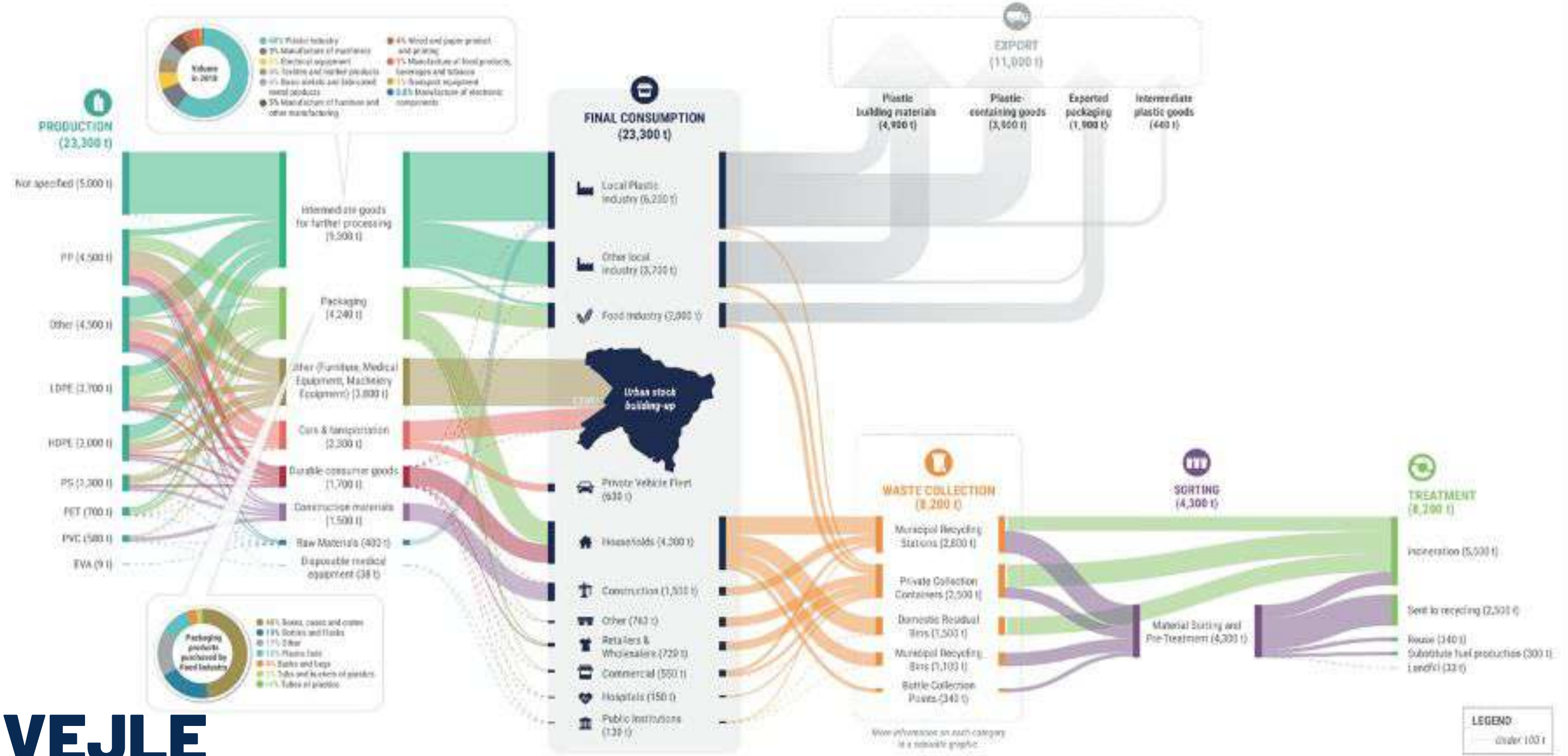


# VEJLE
# CIRCULAR PLASTIC MFA

Material Flow Analysis of plastic production at Vejle, Metabolic at Reflow Project, 2020

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# VEJLE FOOD INDUSTRY

The waste flows from food industry in cities can be divided in these two groups.

***Avoidable food waste***

*Edible*

+

***Unavoidable Food waste***

*Non-edible peels, seeds, etc*

# UNAVOIDABLE FOOD WASTE

*Vejle unavoidable food waste tons per year*

Poultry Meat
641.80

Coffee & Products
584.53

Banana & Plantains
172.52

Eggs
159.70

Potatoes & Products
145.66

Bovine Meat
105.56

Tea
85.29

Pigmeat
71.48

Onion
55.65

Orange & Mandarines
54.93

Pineapples & Products
39.31

Lemon, Limes & Products
16.30

Apples & Products
9.04

Mutton & Goat Meat
7.37

Grapes & Products
7.19

Dates
3.27

Grapefruit & Products
3.27

Fish
1.12

Crustaceans
0.46

Molluscs
0.11

# UNAVOIDABLE FOOD WASTE

*Biopolymer tons from unavoidable food waste per year*

| ***Unavoidable Waste*** | ***Tons*** | | ***Biopolymers*** | ***Tons*** |
|---|---|---|---|---|
| Poultry Meat | 641.80 | → | Collagen (Gelatine) | *96.27* |
| Coffee & Products | 584.53 | → | Cellulose | *50.27* |
| | | | Hemicellulose | *214.52* |
| Bananas & Plantains | 172.52 | → | Cellulose | *20.70* |
| | | | Starch | *25.88* |
| | | | Pectin | *0.43* |
| Eggs | 159.70 | → | Calcium Carbonate | *151.71* |
| Potatoes & Products | 145.66 | → | Starch | *29.13* |
| Bovine Meat | 105.56 | → | Collagen (Gelatine) | *6.33* |
| Tea & Mate | 85.29 | → | Cellulose | *13.65* |
| Pigmeat | 71.48 | → | Collagen (Gelatine) | *4.29* |
| Onions | 55.65 | → | Cellulose | *25.04* |
| | | | Hemicellulose | *11.13* |

# BIOPOLYMERS

Polymers of natural origin derived from renewable resources. These are composed of nature basic building blocks, into larger chains called biomolecules

***Biopolymers*** ***Blocks***


*Cellulose - Chitosan - Starch*

***Biomaterials***

# BIOPOLYMERS

Each biopolymers plays a key role in the composition of biomaterials

**Structural Matrix** + **Reinforcing Material** + **Plasticizer** + **Solvent**

### Structural Matrix

*Biopolymer that agglomerates the material components*

### Reinforcing Material

*Fibre or mineral that fills in the material, enhancing specific properties*

### Plasticizer

*Biopolymer that enhances the flexibility and strength of the material*

### Solvent

*Dissolves the main components that promote chemical catalysis*

# Agar & Gelatin Bioplastic

***Agar-Agar***

*Seaweed Biopolymer*

**+**

***Gelatin***

*Protein Biopolymer*

–

***Glycerine***

*Vegetal or animal triol*

***Water***

*Authors: Maquinar.io*

***Structural Matrix*** + ***Reinforcing Material*** + ***Plasticizer*** + ***Solvent***

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# Agar & Gelatin Biocomposite

***Agar-Agar***
*Seaweed*
*Biopolymer*
**+**
***Gelatin***
*Protein Biopolymer*

**Structural Matrix**

+

***Plant Fibers***
*Cellulose*

***OR***

***Eggshell***
*Calcium Carbonate*

**Reinforcing Material**

+

***Glycerine***
*Vegetal or animal triol*

**Plasticizer**

+

***Water***

**Solvent**

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# Eggshell & Alginate Biocomposite

***Alginate***
*Seaweed*
*Biopolymer*

***Eggshell***
*Calcium Carbonate*

***Glycerine***
*Vegetal or animal triol*

***Water***

*Authors: Labva*

***Structural Matrix*** + ***Reinforcing Material*** + ***Plasticizer*** + ***Solvent***

# Other biopolymers

Chitin
Starch
Pectin
Collagen
Agar
Alginate

Eggshell
Cellulose

Glycerine

Water

Structural Matrix + Reinforcing Material + Plasticizer + Solvent

# CATEGORIZATION

Biomaterials can be categorized by several criteria depending their aim

*Manufacturing techniques*

*Applications*

*Biopolymer*

*Properties & Characteristics*

*Format*

# CATEGORIZATION

***Manufacturing techniques***

## *Crafted*

Mixing ingredients in a solution adding heat and pouring in a mould to shape


**Carrageenan Bioplastic**
*Algae-based*


**Sawdust + Agar**
*Plant and algae-based*

## *Grown*

Growing live microorganisms in a suitable medium


**Kombucha**
*Bacteria-based*


**Mycelium**
*Fungus-based*

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# CATEGORIZATION

## *Application*

## *Packaging*

**Algae Food packaging**
*Margarita Talep*

**Printed kombucha  packaging**
*Labva*

## *Textiles*

**Biothread**
*Carolina Etchevers - Biomatrialista*

**Coffee Bag**
*Fab Textiles*

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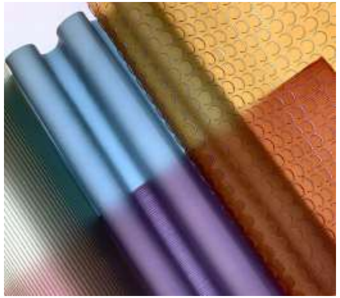
# CATEGORIZATION

***Format***

## *Sheets*

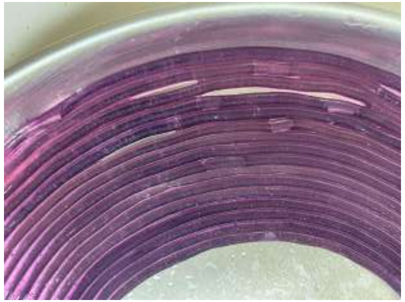


**Bioplastic sheets**
*Youyang Song*

## *Composites*

**Tea and coffee composites**
*Biohm + Caraca Collective*

## *Threads*



**Biothread**
*Xenabeth Lázaro*

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# CATEGORIZATION

*Biopolymer*

## *Cellulose-based*

**Coffee Husk composite**
Big Circle Studio + Zoe Powell

## *Collagen-based*

**Gelatin & Agar-based Sheet**
Maquinar.io

## *Chitin-based*

**Chitin-based cups**
The Shellwork

# BIOMATERIALS BRANDS

## NOTPLA

Algae-based packaging

## PIÑATEX

Pineapple-based textiles

## MOGU

Mycelium-based panels

# BIOMATERIALS BRANDS

## *BOLT THREAD*

Mylo - Mycelium-based fabric

## *CHIP[S] BOARD*

Starch-based boards

## *TOMTEX*

Chitin-based sheets

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# HOW TO MAKE BIOMATERIALS?

# Ask yourself the right questions

# APPROACH DIMENSIONS

Biofabrication Methodology
Biolab Austral

**Reflective Dimension**
*Ethical-critical*

**Territorial Dimension**
*Physical context*

**Social Dimension**
*Key actors*

**Practical Dimension**
*Equipment*

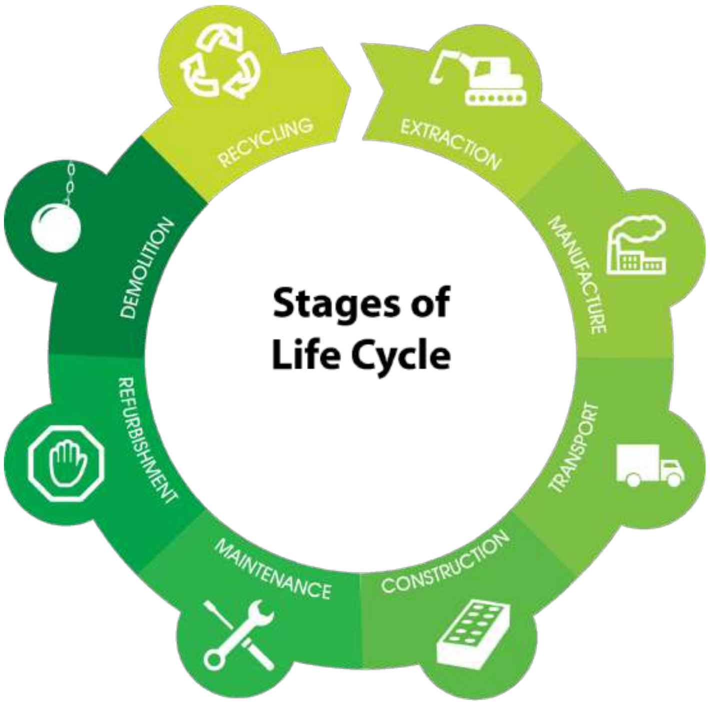
**Technical Dimension**
*Data - Processes*

*Biomateria Austral project. Chile, 2021.*

# REFLECTIVE DIMENSION

## Ethical Critical

*Ethical principles of working with raw materials. It considers energy consumption, inter- and intraspecies relations, and the sustainability of biogeochemical cycles.*




*Irish Green Building Council LCA - www.igbc.ie*

# TERRITORIAL DIMENSION

## Physical Context

*Context associated with the development of the raw material. The intrinsic characteristics of the context are considered, from the type of environment to the structural scales of the site.*

***Denmark Topographic Map***
***Tschubby, CC BY-SA 3.0 Wikimedia Commons***

# SOCIAL DIMENSION

## Key Actors

It considers all those people and organisations involved in the work with biomaterials.

*Biomaterial Workshop*
*Fab Lab Spinderhallerne & Materiom*

# PRACTICAL DIMENSION

## Equipment - Tools

*Involves necessary artefacts or products such as equipment, machines, and tools.*

***Biopolymer Extraction Tools***
***Biomateria Austral***

# TECHNICAL DIMENSION

## Data - Processes

*More specific knowledge about the raw material, as well as the methodology and processes used.*


***Chitin-based biomaterial Materiom & Reflow***

# Start experimenting

# ACTION INSTANCES

Biofabrication Methodology
Biolab Austral


*Biomateria Austral project. Chile, 2021.*

# BIOMASS COLLECTION

Access to the source of the resource or ingredient

- *What resources do I have locally in the environment or from organic waste?*
- *How to use them responsibly so as not to overload the ecosystem?*
- *Who already works locally with this resource? Could I collaborate with them?*
- *Which sourcing method I will use?*
- *What species am I working with? What biopolymers compose it?*

**Walnut Shell**

# BIOMASS PREPARATION

## Extraction and classification of the raw material

- *How to clean, dry and ground my material for later use?*
- *Work with already processed resources or extract them directly from the biomass?*
- *How to document my process and registre my exploration?*
- *What role does each element of my biomaterial play? Is it similar to its role in nature?*

***Materiom***
***Orange Peel Processing***

# BIOMASS PREPARATION

Tips

| Processing biomass | Kitchen equipment | Maker equipment |
| --- | --- | --- |
| **Dehydrating** | *Sun/ Oven at 35ºC with fan* | *Dehydrator at 35-40º* |
| **Grinding** | *Blender / mortar and pestle* | *Shredder* |
| **Sieve** | *Kitchen Sieve* | *Mesh sieve strainer* |
| **Storage** | *Jars* | *Airtight container* |
| **Labeling** | *Name, Biomass, Dates* | *Name, Biomass, Dates* |

# SAMPLE PRODUCTION

## Biomaterial fabrication process

- *What tools and machines do I need?*
- *How will I measure my ingredients to control changes and facilitate scanning?*
- *Which formats do I want to explore? Films, blocks, yarns?*
- *How will I dry my samples once they are ready?*
- *How will I categorise and label my samples? By biopolymer, application, format?*

***Elia Gasparolo***
***Material Development***

# SAMPLE PRODUCTION

## General Tips

| ***Processing recipe*** | ***Kitchen equipment*** | ***Maker equipment*** |
|---|---|---|
| ***Cooking*** | *Pot, kitchen stove, measuring cups, stirring spoon, kitchen thermometer* | *Container, hot plate, precision scale, silicone spatula, digital thermometer* |
| ***Moulding*** | *Silicon, Metal Containers* | *Laser cutted molds, thermoformed moulds* |
| ***Dehydrating*** | *Sun/ Oven at 35ºC with fan* | *Dehydrator at 35-40º* |
| ***Labeling*** | *Biopolymers, Time, Concentrations, Date* | *Biopolymers, Time, Concentrations, Date* |
| ***Documenting*** | *Lab book & Photos* | *Lab Book, Photos & Excel Sheet* |

# SAMPLE PRODUCTION

## Typical issues

| Processing recipe | Kitchen equipment | Maker equipment |
|---|---|---|
| ***Avoid bubbles for material consistency*** | *Tap the solution before gelling in the mold until eliminate the bubbles* | *Use a vibration platform, heat gun or vacuum pump* |
| ***Avoid undesired bacterias and funguses*** | *Clean equipment, cover samples with breathable cloth, not touch material until dry, use preservatives such as Salt, Rosemary or Sage.* | *Sterilise equipment, cover samples with breathable cloth, use dehydrator, not touch material until dry, use preservatives such as Sodium Benzoate, Calcium Peroxide or Calcium Propionate.* |

# SAMPLE PRODUCTION

## Other Tips

| ***Processing recipe*** | ***Process*** |
|---|---|
| ***Thicker materials*** | *Higher concentration of structural matrix/ binder biopolymer, more glycerin, or a reinforcement material like grinded fibers or particles.* |
| ***Flexible and Stronger materials*** | *Increase plasticizer, like glycerin. However, Too much glycerin can make the final material sticky.* |
| ***Material Shrinkage*** | *Reduce the solution as much as possible in the hotplate, use wood framework (silicone or acrylic top), increase glycerin or structural biopolymer.* |

# SAMPLE INTERVENTION

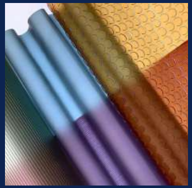
Post-processing and finishing of the material.

- *What tools and machines do I have to work on the samples?*
- *If I use digital fabrication, can I laser cut my material to make textures, assemblies, fold it or engrave it?*
- *Could I use traditional techniques such as sewing machines, scissors or stamping machines?*
- *Is it necessary to add a finish such as oil, wax or pigments? Are these other resources environmentally friendly?*


***Anya Muangkote***
***Biogoods - Agar garments***

# SAMPLE INTERVENTION

## Techniques

| ***Processing material*** | | ***Process*** |
|---|---|---|
|  | *Sheets* | • *Use flat moulds without fillers, just the structural biopolymers and glycerin.*<br>• *Depending on your recipe, it may react better with different mould materials, such as silicone, melamine, acrylic, metal, etc.* |
|  | *Composites* | • *Balance well the liquid solution with the filler. Too much liquid can result in materials with different thickness, and not enough can result in fillers that do not agglomerate.*<br>• *You can add pressure to avoid gaps between your fibers or particles.*<br>• *Drying may take longer than thinner biomaterials, therefore they may be more prone to bacteria and fungi.* |
|  | *Threads* | • *Use syringes o 3d printers.*<br>• *It is recommended to create materials based on sodium alginate and pour in calcium solution.* |

# SAMPLE INTERVENTION

Digital Fabrication

***Laser Cutter***

***Vector Cutting & Engraving***


*For flexibility and textures*

***Half-Vector Cutting***


*For folding and origami*

***Vector Cutting & Modules***


*For modules and joints*

# SAMPLE INTERVENTION

Digital Fabrication

***3D Printing***

### *Printing Solutions*

Dummo Lab - Tuft University

### *Printing Composites*

Delft University
Sauerwein, Doubrovski & Vette

### *Printing Moulds*

Fab Lab U Chile & J. Rosas

# SAMPLE INTERVENTION

Digital Fabrication

***Router CNC***

***Machining Composites***

Biobabes

***Machining Molds***

*Biohm + Caraca Collective*

# SAMPLE INTERVENTION

## Other techniques

### *Foaming*

*Paula Nerlich*

### *Press Heating*

*Anya Muangkote*

### *Textured Molds*

*Clara Davis*

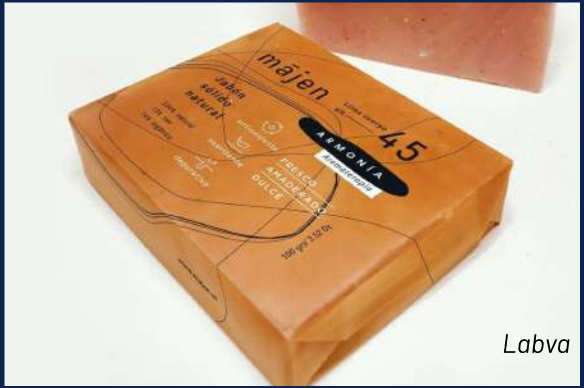
# SAMPLE INTERVENTION

## Other techniques

### *Silkscreen Printing*

*Labva*

### *Ink printing*




*Labva*

### *Sewing*

*Charlotte McCurdy*

# CHARACTERIZATION

Defining applications according to technical-sensory test

- *What are the aesthetic and sensorial characteristics of my material?*
- *What physical and chemical properties does my material have? How can I test this?*
- *For which applications are these characteristics and properties useful?*
- *Can I enhance certain properties by changing the ingredients, their concentrations or the format of my material?*

***Fab Lab U. de Chile***
***Biomixer - Nodo Biofabricación Digital Project***

# SAMPLE CHARACTERIZATION

## Physical characterization

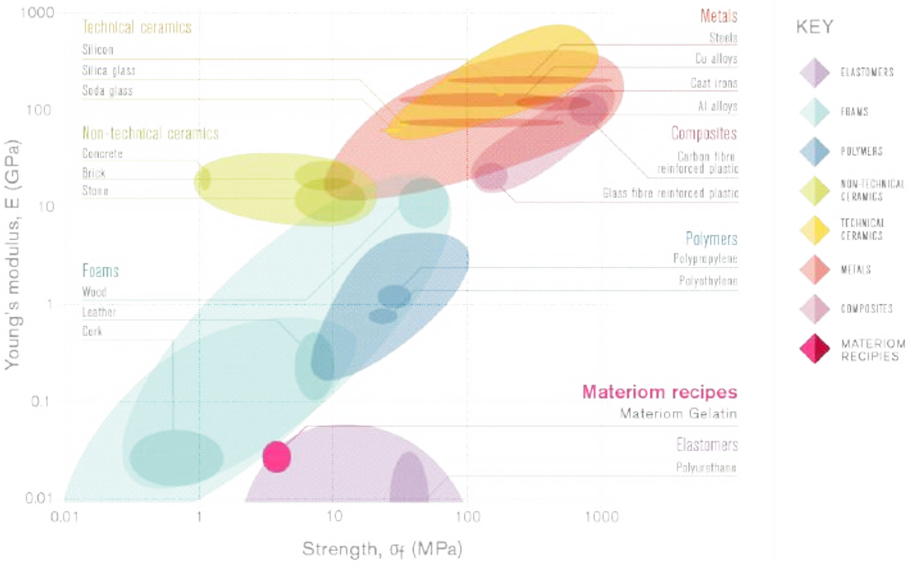
*Colour, Opacity, Weight, Size, Density, etc*

## Mechanical characterization

*Hardness, Tensile testing, Toughness, Compression, etc*

## Chemical characterization

*Ecotoxicology, Biodegradability, etc*




***Ashby diagram***
***Materiom***

# BIODEGRADATION

Reincorporation into the ecosystem at the end of life-cycle

- *Is it possible to continue using my biomaterial? Should I replace certain elements?*
- *Is it possible to recycle and re-cook my biomaterial?*
- *In which medium do I want to biodegrade my sample? Water, compost?*
- *What concentrations of this material are suitable for the ecosystem?*
- *Could the biodegradation of my material have a use such as nutrient delivery?*

***Ecovative***
***Mycelium-based Biodegradable Packaging***

**Share your recipe at www.materiom.org !**

# Keep researching

# MORE RESOURCES

*Review our masterclass!*

*Materiom.org*

*Reflowproject.eu*

*Ellenmacarthurfoundation.org*

*Asknature.org*

*Biomimicry.org*

*Biomimicry.net*

*Gbif.org*

*Iom3.org*

*Materialconnexion.com*

*Materialinnovation.org*

*Material-exchange.com*

*Materialdistrict.com*

*Healthymaterialslab.org*

*Fabtextiles.org*

*Futurematerialsbank.com*

*Openmaterials.org*

*Instructables.com*

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# Thank you!

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