PITS AND PEELS - Food Waste Biomaterials

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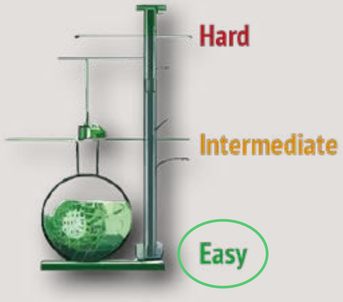
From https://naifactorylab.com/en/biomateriales-2/

Have you ever imagined making a table top out of olive pits?
Or even a toy made of avocado peels?

Timeline

Days

- Day 1: 30 minutes
- Day 1: Make 40 minutes
- Day1 to 4: Dry from 6 hours -to 4 days



1|ABOUT

This CoCoon module continues to use food waste, exclusively inedible by-products such as pits and peels, as resources for sustainable design. Reimagining food waste can help drive new material innovation.

1.1|The Problem/Scenario “context”

Global priorities shifted from traditional linear resource use to a circular bioeconomy model. Nowadays, we aim to minimise waste and protect and restore ecosystems by using renewable biological resources (Sekabira et al., 2022) and their waste to create value-added products.

In botanical terms, a “seed” refers to a mature ovule containing an embryo, food reserves, and protective covering capable of growing into a new plant. Meanwhile, a “peel” or fruit skin is the outer protective covering of fruits.

Fruit peels and seeds contain many bioactive compounds with promising culinary, pharmaceutical, and design applications. These ingredients meet the rising demand for natural ingredients and are favoured for their lower risk of adverse effects compared to synthetic additives.

Researchers have extensively studied various fruit seeds’ and peels’ functional properties, proximate composition, and mineral content (Allaqaband et al., 2023). However, only 0.5% of fruit waste is repurposed, leading to pressure on landfills and significant waste of valuable natural resources (Nasrollahzadeh et al., 2020).

For example, date seeds, constituting around 11.3% of a date’s weight, are largely discarded as waste in date-growing regions (Mubaiwa et al., 2024). Similarly, citrus juice production yields large amounts of waste—peels and seeds comprise up to 95% of the fruit mass (Lucia et al., 2022). In Taiwan, mango seed waste alone can reach up to 63,000 tons annually (Lin & Zheng, 2021). Apple processing produces 20–30% solid waste, including seeds and peels (Dhillon et al., 2013), while global papaya processing generates roughly three million tons of waste annually, with seeds making up 70% (Castro-Vargas et al., 2019).

These biodegradable fruit wastes are poorly managed and pose environmental risks. They could cause eutrophication, pollution, and greenhouse gas emissions, impacting ecosystems and human health (Bhoi, 2024).

To combat this scenario, once disregarded and discarded, fruit seeds and peels gain our attention for their valuable compounds. So, let’s transform them into biomaterials!

1.2|What is the module

The aim is to develop biomaterials, mainly bioceramics, from local food waste: fruit pits and peels (PITS and PEELS) to produce bio-based crafted products that are organic, bio-compostable, and biodegradable.

Games developed by students - Biolab Cocoon

1.3|What is the Organism / Material

According to Feumba (2018), peels represent almost 30% of the total weight of some fruits and are the primary by-product. His study aimed to investigate the chemical composition of fruit peels from selected fruits (orange, watermelon, apple, pomegranate, pawpaw, banana, pineapple, and mango).

The results showed that fruit peels contain lipids, protein, ash, crude fibre, carbohydrates, and minerals such as calcium, zinc, iron, and manganese. Concerning anti-nutrients, oxalates, hydrogen cyanides, phytates, and alkaloids, levels in fruit peels were within the threshold value reported as the safety limit.

Additionally, the seeds and kernels of fruit are “considered remarkably rich sources of sodium, potassium, zinc, copper, iron, fatty acids (linolenic, oleic, palmitic, and linoleic acids), fibre, and carbohydrate (sucrose, glucose, and fructose) content” (Kumari et al., 2023).

1.4|Explain the Process

After sourcing the pits or the peels, the process is relatively quick and similar to the POD module. It starts by drying and powdering the material. We aim to get the fibre, ensuring the rigidity of the bioceramics we will make.

This powder will be mixed with the gelatine and water solution. The gelatine is the binder, and the water is the solvent. Both need to be heated (in a water bath) and simmered for 10-15 minutes until they are homogeneous and ready to be poured into the moulds.

HARM LESS
from https://www.instagram.com/harm__less__/?hl=en

HEALTH AND SAFETY

BSL-1

For work involving BSL-1 organisms, such as non-harmful bacteria, a sterile lab is not strictly necessary, but a clean and controlled workspace is essential. You can conduct these activities in a well-maintained studio or similar environment outside of a traditional laboratory, provided the space is organised and protocols are in place to minimise contamination and ensure safety. Ensure that surfaces are disinfected before and after work, and avoid areas where food is prepared or consumed. Additionally, restrict access to the workspace during experiments to avoid unintentional exposure or contamination of materials.

SPACE

•Lab environment
(bioFABLAB, biology classrooom or a very clean kitchen canbe use

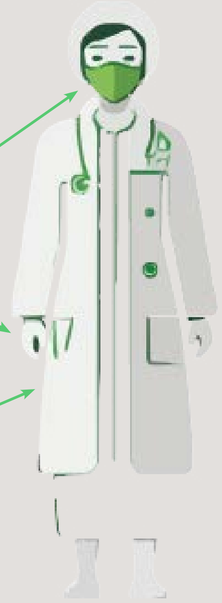
•Access restrictions
(guests can bring new contaminants)

STYLE

•Glove up
(witch clean hand)

•Mask up
(nose and mouth)

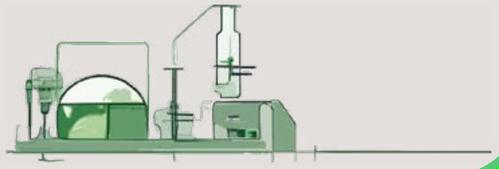
•Dress up
(like a pro)



STERILISE

•Ingredients
(keep ingredients in closed containers)

•Tools
(clean all tools)



•Tables
(clean all surfaces and workbenches)

CHECK BOX

INGREDIENTS

- [ ] Gelatine
- [ ] Water
- [ ] Glycerin
- [ ] Vinegar
- [ ] and chosen material

SPACE AND EQUIPMENT (KITCHEN AREA)

Kitchen area:

- [ ] Clean table
- [ ] Oven
- [ ] Kitchen stove
- [ ] Refrigerator
- [ ] Sink with tap

TOOLS & EQUIPMENT

- [ ] Cooking pot
- [ ] Measuring cups
- [ ] Kitchen scale
- [ ] Stirring spoon
- [ ] Rubber spatula
- [ ] Sieve (5mm) if you want to use the same granulometry

HEALTH AND SAFETY EQUIPMENT

- [ ] Isopropanol
- [ ] Sterile gloves
- [ ] Oven mitts

DESIGN CASING (CONTAINMENT)

- [ ] Silicone mould

STERILISE ALL CASING EQUIPMENT THOROUGHLY

Time
Day 1: Prep 30 minutes
Day 1 - 7: Make 40 minutes
Days 1 to 4: Dry 6 hours - 4 days

Prep Powder
1-Clean dry
2-Grind eggshells down to fine particles
3-Store in the refrigerator in a sterile glass jar

Make mix
1-Mix water with gelatin into a pot.
2-Mix powdered.
3-Stir and let simmer at medium temperature.
4-Pour into clean silicone moulds and let it dry.

Dry design
1-Heat oven to the lowest setting (45°celcius)
2-Place moulds in oven for 6 hours
3-Check regularly for cracks while the design is drying

Finalising your design.
1-Demould your design
2-Spray your design with vinegar to prevent contamination.

TIP!

PREPARE: Measure all ingredients and place them in separate containers

Natural drying: You can choose to dry your design out naturally. This is best achieved in shade with good ventilation.

STERILIZE: Always sterilise tools and surfaces, then handle all ingredients with clean hands

OBSERVE: Always watch your final product as it is drying [for cracks or contamination].

PROTECT: You can spray vinegar over your finished products to prevent contamination [mould, fungus, etc] during the drying process.

2|SETTING UP

We focus on exploring household food waste, but if production is to be scaled up, sourcing material can be extended to local restaurants, cafes, bakeries, or even farmers.

2.1|Sourcing the pits and peels

Every time that you eat a fruit, please save its pit and peel. Ask your friends or family, local restaurants or even your school canteen to see if they could also save and give them to you.

From https://www.simpleecology.com/blog/5-ways-to-repurpose-your-food-waste

2.2|Buy other ingredients

Only water and neutral gelatine are used as secondary ingredients. Gelatine, easily found in local supermarkets' baking sections, is commonly used to make jelly, but it has to be neutral because we do not want sugar and other elements in our recipe!

Ingredients:
- ☐ Gelatine
- ☐ Water

TIP!

- Try to buy in retail stores in larger quantities, so that the value of the unit has a fair price.
- And always in local stores.

2.3|Space and tools

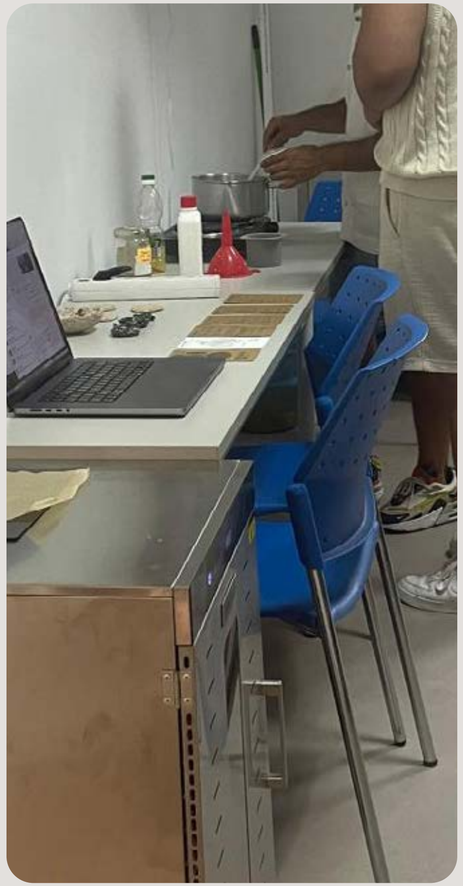
A kitchen is ideal as it generally contains a clean working table, a stove, a sink with tap water, and electricity. Most of the tools used in this recipe, such as a spatula, scale, and measuring cups, are also found there.

Tools:
- ☐ Pot
- ☐ Spatula
- ☐ Kitchen Scale
- ☐ Measuring Cups

2.4|Specific equipment

The tools and equipment to prepare the materials are:

- **•Sink to wash the ingredients,**
- **•Dehydrator for drying,**
- **•Food-crushing machine or a grinder or a mortar,**
- **•Cooking pots,**
- **•Scale / Measuring cups.**



BioLab Cocoon

2.5|Moulds and Containment

We recommend using silicone moulds to easily remove your bioceramic object. However, if you use other types of moulds, you can treat them with oil or parchment paper.

BioLab Cocoon

TIP!

•You can easily find and buy silicone moulds on the internet!

3|PREPARE

3.1|Health and Safety

Carrying out the activities in the laboratory or even at home does not pose a risk. Nevertheless, always be careful when using the tools to avoid getting hurt. For young practitioners, we advise having adult supervision for all stages.

Pits and peels are not harmful to humans unless there is an allergy.

3.2|Clean and Powder the materials

Clean all tools before use and spray surfaces with isopropanol.

To dry the pits and peels, you need a clean container, oven, or dehydrator.

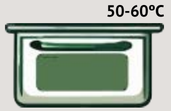
TIP!

•Always handle the materials with clean hands! Always sterilise tools and work surfaces! And wear a clean apron or lab coat!

TIP!

• The total drying or dehydration of food residues is an essential step in the production of bioceramics. This process involves removing free water from the base material used in the recipes, preparing it for future chemical transformations and preventing the growth of microorganisms.

There are several ways to dry the raw materials used in these recipes:



1-Sun Drying, ideal for warm and dry regions:
Place the materials on trays, protecting them with fine mesh screens to keep insects away. This method requires several days and constant monitoring to prevent contamination.
2-Oven Drying, suitable for domestic environments: Set the oven to a low temperature (around 50–60°C) and keep the door slightly open to allow moisture to escape. Turn the base materials regularly to ensure even drying.
3-Electric Dehydrators: It is an efficient and controlled method, as dehydrators are equipped with ventilation and temperature control, ensuring quick and uniform drying.

Suppose the base material dries unevenly (e.g., some areas remain damp while others are dry). In that case, internal tensions may develop, leading to micro-cracks and a potential loss of strength. Removing water also inhibits the growth of bacteria, fungi, and yeast, extending the lifespan of the biomaterial.

Then, you will need a good food processor to powder them.

After powdering, store the material in a clean container.
There is no need to store them in a refrigerator.

Now let's move on to the next step —Transformation!

TIP!

• Grinding time will change the granule size of your dry ingredients. Longer grinding time will give you a finer texture. Adjust to your liking.

Preparing the pits or peels powder, from https://www.koukosdelab.com/koukoutsi

Preparing the pits or peels powder, from https://www.koukosdelab.com/koukoutsi

4|GROWTH/MAKE/TRANSFORMING/APPLY ETC.

4.1|The process

A kitchen is ideal as it generally contains a clean working table, a stove, a sink with tap water, and electricity. Most of the tools used in this recipe, such as a spatula, scale, and measuring cups, are also found there.

We will need these tools:
- ☐ Pot,
- ☐ Spatula,
- ☐ Scale / Measuring cups,
- ☐ Silicone mould sterilised.

And these ingredients:
- ☐ Powdered pit or peel,
- ☐ Gelatine,
- ☐ Water.

For the correct amount of material, see the available recipes in the next pages.

TIP!

•Measure the ingredients before you start mixing.

4.2|Recipes

AVOCADO SEED BIOCERAMIC

For the rigid biomaterial made from avocado seeds, the quantities are:
- ☐ 20g neutral gelatine powder
- ☐ 225ml water
- ☐ 100g avocado seed (cleaned, dried, and powdered).

BANANA PEEL BIOCERAMIC

For the rigid biomaterial made from banana peel, the quantities are:
- ☐ 20g neutral gelatine powder
- ☐ 100ml water
- ☐ 9g glycerin
- ☐ 20g banana peel (cleaned, dried, and powdered).

GINGER PEEL BIOCERAMIC

For the rigid biomaterial made from ginger peel, the quantities are:
- ☐ 20g neutral gelatine powder
- ☐ 100ml water
- ☐ 40g ginger peel (cleaned, dried, and powdered).

LUPINE PEEL BIOCERAMIC

For the rigid biomaterial made from lupine peel, the quantities are:
- ☐ 2 soup spoons of nature glue*
- ☐ 80g lupine peel (cleaned, dried, and powdered).

ORANGE PEEL BIOCERAMIC

For the rigid biomaterial made from orange peel, the quantities are:
- ☐ 20g neutral gelatine powder
- ☐ 200ml water
- ☐ 100g orange peel (cleaned, dried, and powdered).

POMEGRANATE PEEL BIOCERAMIC

For the rigid biomaterial made from promegranate peel, the quantities are:

- ☐ 20g neutral gelatine powder
- ☐ 70ml water
- ☐ 100g promegranate peel (cleaned, dried, and powdered).

POTATO PEEL BIOCERAMIC

For the rigid biomaterial made from potato peel, the quantities are:

- ☐ 20g neutral gelatine powder
- ☐ 100ml water
- ☐ 100g potato peel (cleaned, dried, and powdered).

PUMPKIN PEEL BIOCERAMIC

For the rigid biomaterial made from pumpkin peel, the quantities are:

- ☐ 20g neutral gelatine powder
- ☐ 50ml water
- ☐ 100g pumpkin peel (cleaned, dried, and powdered).

COFFEE GROUNDS BIOCERAMIC

For the rigid biomaterial made from coffee ground, the quantities are:

- ☐ 20g neutral gelatine powder
- ☐ 50ml water
- ☐ 100g avocado seed (cleaned, dried, and powdered)
- ☐ 20ml vinegar.

NOTE! The recipes brought to Cocoon's project are from the project "BiomaterialKIT—Practical and Pedagogical Experiment for More Sustainable Consumption" - TR2020/DG/01/A2-01/1551, a cooperation between the Portimão and Bayraklı municipalities through ISMAT/COFAC and Izmir Economics University.

NATURAL GLUE

Ingredients

- ☐ 1 glass of maize starch
- ☐ 3 glasses of water
- ☐ 1 soup spoon of vinegar

Description

Step 01: Mix the glasses of water with the glass of maize starch in the cooking pot
Step 02: Stir to get a homogeneous mix
Step 03: Turn on the cooker (medium temperature) and stir until it starts to look like a PVC glue
Step 04: Turn off the cooker, add the soup spoon of vinegar, and stir
Step 05: Store in a container with a lid

Time

25 minutes

4.3|Mixing the ceramic

A kitchen is ideal as it generally contains a clean working table, a stove, a sink with tap water, and electricity. Most of the tools used in this recipe, such as a spatula, scale, and measuring cups, are also found there.

1-Mix the gelatine with the water in a pot,
2-Put the pot in a water bath and stir until the gelatine has dissolved,
3-Add the material (pit or peel) and stir until you get a homogeneous mix (approximately 10-15 minutes)

Biomaterials samples by Zsófi Zala, from https://hypeandhyper.com/harm-less-biodegradable-design-objects/

4.4|Moulding

Moulding:
1-Sterilise the silicone mould with isopropanol,
2-Pour the mixture into it,
3-Let the mixture stand for a few days until it is dry.
Now your piece is ready for drying!

4.5|Drying

You can let the piece dry naturally or use the oven at the lowest possible temperature (45° Celsius or using just its fan). The drying time depends on the thickness of the material.

Constantly monitor your final product as it dries and check for cracks or contamination. During drying, some objects' parts may deform. To avoid that, the drying process should be as gradual and uniform as possible. Meanwhile, to avoid contamination, spray a little bit of vinegar on the drying surface.

Demoulding by NaifactoryLAB
from https://naifactorylab.com/en/project

TIP!

•Fab Labs should have moulding and casting equipment that allows you to create a mould.
• You can also let your design dry naturally for a couple of days. Then, it will be less prone to cracking, but contamination will become more likely. Natural drying is best achieved in a clean, shady space with good ventilation.

5|HARVESTING AND POST-PROCESSING

After 2-5 days, the object should be ready to be removed from the mould. This “harvesting” time depends on the environmental conditions, mainly temperature and moisture percentage.

5.1|Demould

Demould:
1-Carefully remove your design from the mould
2-Check for cracks or contamination

Cracks are difficult to solve; you could try glueing them together using a small quantity of the same biomaterial. You can also stop contamination by rubbing a little alcohol gel on the mouldy area.

5.2|Protect

Protect:
1-Spray your design with vinegar to protect it.
2-Play with your design, and choose your next steps ... paint, polish or break.

TIP!

•Do not heat or pour hot water over the object or leave it in direct contact with the sun’s heat, as gelatine tends to break down at high temperatures.

Project from student Pedro Medeiros (ISMAT)- (IF AWARD 2024)

6|DISPOSAL

We encourage circularity. The bioceramics you can make with this module are biodegradable, so they can be absorbed by the earth's soil and converted back into natural elements. Moreover, pollution is prevented. Although unmaking has been presented as a friend of sustainability, we strongly advise bringing up concerns about repair, deterioration, and decay as early as possible in the biodesign process.

TIP!

•Simplicity for nature

Cocoon Lab

7|GET INSPIRED

7.1. What has been done?

Get inspired! Here are some links to some works.

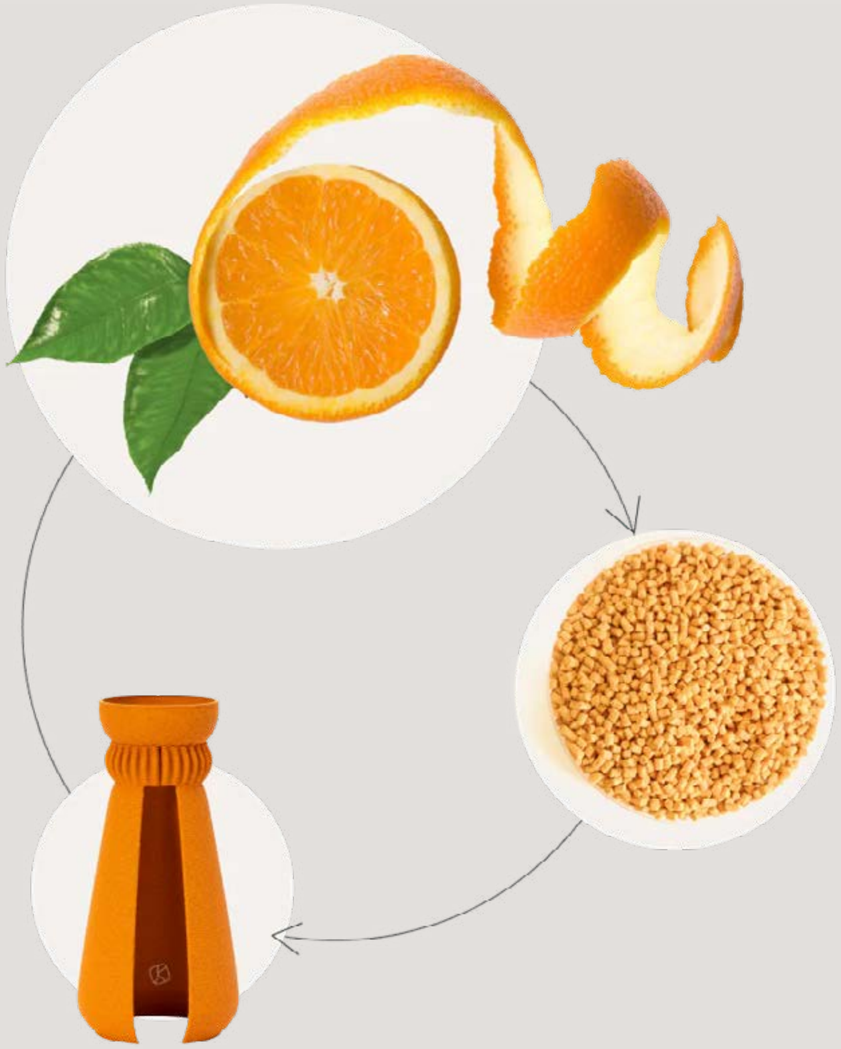
Koukos de lab

Koukos de lab
from https://www.koukosdelab.com/products

Koukos de lab
from https://www.koukosdelab.com/products

NaifactoryLAB
from https://naifactorylab.com/en/

Carlo Ratti Associati / 2019 , from https://carlorattiassociati.com/project/feel-the-peel/
https://www.dezeen.com/2019/09/10/carlo-ratti-feel-the-peel-circular-orange-juice-bar-design/



Krill Design / 2018-ongoing
from https://en.krilldesign.net/pages/shop

Caracara Collective
from https://www.caracaracollective.com/design-matters-bildmuseet

HARM LESS
from https://www.instagram.com/harm__less__/?hl=en

HARM LESS
from https://www.instagram.com/harm__less__/?hl=en

OTTAN STUDIO
from https://www.ottanstudio.com/project

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