Appendix A to report OYSTERWORKS

MATERIAL EXPERIMENT JOURNAL

Diploma Project – Fall 2022

The Oslo School of Architecture and Design

Hanna Tørstad

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THE MATERIAL EXPERIMENT JOURNAL

The Material Experiment Journal has been a tool in the first step of the project's exploration phase – "understanding the material", through material tinkering. I have used the journal to keep track of all the experiments with input and outcomes. The journal documents my learning process with the material, starting with the basics of bio-based materials; understanding the terms, the components and how they work in theory.

Then, through experimentation, learning how they act together and what affects the result. Throughout the process the recipes and methods are tuned and combined to create new experiments with various material properties and qualities. The experiments are documented with pictures and notes of findings and observations.

The documentation includes the ingredients and process, making the experiments available and possible to reconstruct by others, or work as an overiview and inspiration to create other bio-based materials.

The course "Local bio-based materials" has been important to get to know the ingredients and has inspired the recipes, together with recipes from "Bioplastic Cook Book" By Margaret Dunne.

TERMS AND DEFINITIONS

Starting this project I had limited knowledge about biomaterials and quickly encountered some new terms. I have often seen the term biomaterial or biobased used in both product and fashion industry, but what does it really mean? Is it natural? Sustainable? Biodegradable? And is "bio" always better? I do not have answers to all of these questions, but in order to understand and use some of the terms in the project I needed to clarify some definitions.

The "bio" terms are many, and my impression is that there is a lack of broadly agreed upon definitions for many of the terms in this category. The definitions that follow are my understanding and interpretation of the terms through the course "Local bio-based materials" and research on the topic, and explains what I mean when I use them in this project.

BIO-BASED MATERIALS

“Biomaterials” or “biobased materials” refers to materials that mainly consist of a substance derived from living matter and occur naturally. It includes materials, fully or partly derived from plants, trees, fruit, animals and more (excluding those derived from fossil sources). Bio-based materials are often biodegradable, but not always (Dunne 2018, 2).

BIOPLASTIC AND POLYMERS

Plastics are made from long chains of molecules called polymers. Different polymers and combinations make different types of plastics. Bioplastics are made from polymers derived from plant sources, rather than petroleum. If mixed with other ingredients and “cooked” precisely, the biopolymers can be turned into bioplastics. Bio plastics are generally composed of a biopolymer, a plasticizer and a solvent.

BIOCOMPOSITES

A composite is a combination of two or more materials with different properties, which function together, but are not dissolved or merged into each other. The composite is formed by fibers of or particles acting as a reinforcement filler, embedded into a polymer matrix surrounding it. The final material holds other properties and qualities than one of the components alone would. In biocomposites the fibers or particles are bio based and the matrix is a biopolymer.

BIODEGRADABLE AND COMPOSTABLE

These terms have proven difficult to define in a simple way. After conversation with a chemist Magne Solvåg-Mathisen, I learned that this isn’t always straightforward and sometimes complex to determine in which category a material is.

In an attempt to simplify it, one can say that a biodegradable material decomposes naturally over time. It breaks down into non-harmful substances by microorganisms and natural processes. The time frame for the decomposition varies.

Bio compostable materials require specific conditions in order to decompose back to their natural elements, with the help of microbial dissolution. To undergo this process the right level of heat, water and oxygen is needed. The compost har many uses, as it releases nutrients into the soil.

COMPONENTS AND INGREDIENTS

The following pages gives an overview of the ingredients used in the material experiments, with a short description of what they are and how they act when added to the materials.

The materials mainly consists of thress main components; a polymer, a solvent and the shell particles. Some also includes a plasticizer and other additives. All the ingredient are easy to get hold off, and are sold in convineient stores or health food stores.

BIOPOLYMERS

Polymers are the main component of plastic products. They are chemical compounds consisting of long flexible molecule chains, more or less entangled with each other. Depending on the friction between the chains, the polymer can either be plastic or have a glass like character (biomaterial course).

Biopolymer is a collctive term for all polymers that are part of living organisms. These are, for example types of proteins, acids, natural rubber, polysaccarides such as cellulose, starch, alginate, glycogen and more. Biopolymers used in the following material explorations are gelatine, starch, gum arabic and agar agar.

Starch

Starch is a biopolymer consisting of glucose (sugar chains). Starch is formed in plants by photosynthesis, and can be found in potato, corn and tapioca root among others. Starch is white, tasteless and odorless powder. Needs heat to dissolve in water and bond hydrogen. I've had good results mixing starch with the other ingredients and cold water, then heated it in the microwave while in the mold.

Agar Agar

Agar agar is also a biopolymer made from sugar polymer chains. Agar is extracted from certain red algaes. It is often used as a vegan alternative to gelatine. Agar is almost odorless and tasteless, it swells in cold water and dissolves in boiling water. Bioplastics with agar are prone to shrinking and deformation.

Gelatine

Gelatine is a biopolymer extracted from skin and bones from animals. It is a mixture of protein and collagen. Gelatine can be bought either as powder or thin sheets. It dissolves in hot water, and forms a gel substance when cooled. Gelatine comes in different "bloom" strenghts, ranging from 30 to 325 – with 30 being the softest and 325 being the stiffest. Very strong plastics and foams kan be made with gelatine.

Gum Arabic

Gum arabic, is a tree exudate obtained from the stem of the Acacia tree and other acacia tree species. Chemically it mainly consists polysaccharides . Gum arabic dissolves in cold and hot water. It is sold dried in crystal-like lumps and as powder form. Gum arabic can be used as a basic ingredient of familiar foods like marshmallows, chewing gum, and licorice.

PLASTICIZER

A plasticizer is added to a material to make it softer and more flexible - to increase its flexibility and decrease its viscosity. Plasticizers are added to polymers to meet the demands of the end of product's application.

The plasticizer creates space between the polymer chains, weakening the intermolecular forces and reducing ridigity. It helps to make the chains slip along each other, which make the plastic material more felxible. Also in more brittle or solid materials plasticizers are needed to avoid crisp materials that break easily (biomaterial course).

Glycerine

The plasticizer used in the following material experiments is glycerine - a viscous, colorless liquid that tastes sweet Glycerine bindes water and is a basic ingredient in cosmetics and moisturisers.

Glycerine acts as a plasticizers, and adding it to the polymer solution will create a more flexible and soft material, and less will result in a more brittle and harder material. Glycerine can be both animal and plant based.

SOLVENT

A solvent is added to make the other components dissolve, mix up and form a solution. The solvent helps loosen up all the long polymer chains.

Water

Water is used as the solvet in all the material experiments.

ADDITIVES

Other components can be added to the solution to affect the material properties. In the following material tests dish soap, vinegar and sugar is added.

Surfactant/soap

Dish soap is added to create a foamlike material. Dish soap is a surfactant and naturally forms bubbles. The surfactant traps air in a solids or liquids and helps stabilize foam materials and increase the elasticity.

Acid/Vinegar

Adding a small amount of vinegar to the solution allows the biomaterial to be more flexible. Vinegar is a weak acid and helps break down the polymer chains, especially starch, into smaller sizes and weakens the polymer strenght. The vingear doesn't directly soften the material, but help avoid brittle materials. Too much vinegar can cause the material to never dry.

Sugar

When Gum arabic is used as the biopolymer, adding a little amount of honey or sugar to the solution keep the material from becoming brittle.

KITCHEN LAB

When working with biomaterials and the chosen ingredients for the experiments, it is safe and possible to conduct the experiments in a kitchen with few and simple tools. This has been essential for being able to carry out many experiments in a short time. The steps of the process and all the equipment required are listed below.

PROCESS

Heat or dry
Dry < 100 °C
Heat 250 °C
Heat 950 °C

Crush + Grind
To particles or
fine porwder

Measure
Particles, Solvent
Polymer and Additives

Mixing
Mix the ingredients
cold or over heat

Casting
In non-stickmold,
silicone etc.

Dry
Air dry, low heat in
oven or microwave

Unmold
As soon as possible,
let continue to dry

EQUIPMENT AND TOOLS

→ Grinder
→ Sifter
→ Scale
→ Milliliter measure
→ Bowls in different sized
→ Hand whiskers
→ Metal spoons
→ Plastic containers + lids
→ Pans for cooking
→ Hobs + oven
→ Microwave oven
→ Silicone molds

INITIAL EXPERIMENTS

Before starting to experiment with the Pacific oyster shells I did a series of initial experiments creating bioplastics, foams and composites. Making plastics with fewer ingredients and shorter drying time was a faster way to get to know the different polymers, how they act, and how the ratio between the components changes the result and material properties. I also experimented with eggshell as particles in a composite material, which is easier and quicker to prepare than the oyster shells. It was also a good practice to test out different casting methods, what molds and surfaces work the best. The initial experiments are based on recipes received through the "Local bio-based materials" course and the open source book "Bioplastic Cook Book" by

TIPS AND TRICKS

A few tips and tricks when working with biomaterials, learned through failing experiments.

→ Remove the material from molds or surface as soon as possible (when dry enough) to allow **airflow** on all sides of the material and minimize the drying time.

→ Some materials, like gelatine-based ones, can become very strong. Add some grease on the surface and **remove from mold** as soon as possible to avoid it to get stuck.

→ **Avoid touching** the material more than nessecary before it is completely dry and keep the equipment clean to avoid contact with bacteria. Espcially when working with ingredients like agar and aliganiate.

→ To avoid lumps in the solution **mix in with cold water** before heating. do not mix too heavy during the heating to avoid creating froth.

→ **Expect bioplastics to shrink** as the solvent evaporates during the drying process. Materials without or low on glycering are likely to shrink more.

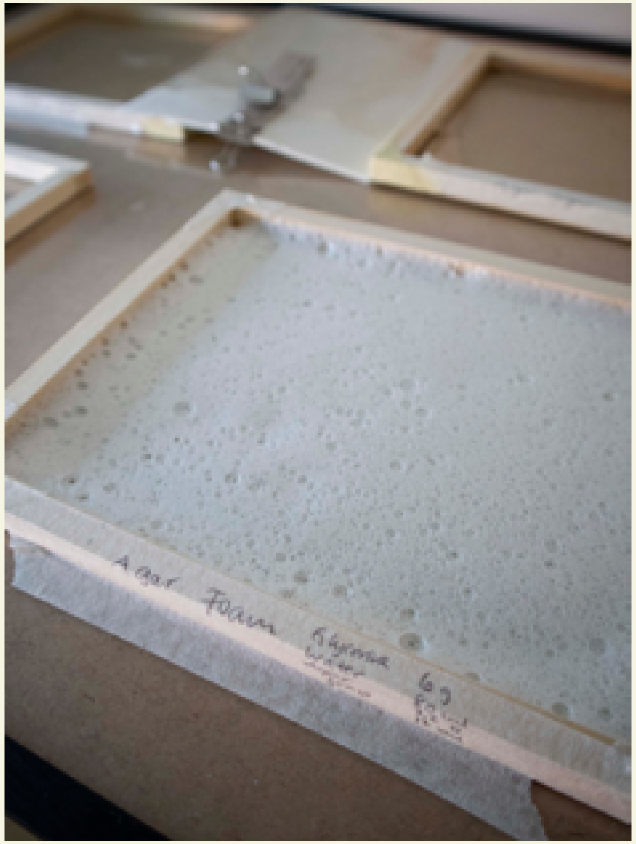
BIOPLASTIC

Agar agar

Agar agar

Gelatine

BIOFOAM



Agar agar

Agar agar

Gelatine

BIOCOMPOSITE

Gelatin + eggshell

Starch + eggshell

Gum arabic + eggshell

HEAT TREATMENT

In order to use the oyster shells in a biocomposite they need to be crushed or grinded into smaller particles to be mixed with the polymer matrix. It proved to be difficult to break the shells into small pieces from the raw untreated state, and I therefore looked into heat treating them to make them more porous and breakable.

The oyster shells, which are marine skeletons, are mainly (96%) composed of Calcium carbonate ($CaCO_3$), some organic materials and mineral traces. The Calcium carbonate can be converted into Calcium oxide (CaO) using heat treatment at high temperature, from 850°C (Sadeghi et al. 2021.). After conversion to calcium oxide, the shells must be handled with precaution as it is corrosive in contact with water.

The shells have some residues and surface impurities, which I remove prior to the heat treatment by hand washing. The oyster shells have been treated at three different temperatures; 50-100°, 200-250°C and 950 °C.

↑ Pacific oyster shells heated at 950 °C in a ceramics oven

HEATED AT 950°C

The shells turn completely white and all the **biological material is decomposed**. There is a sharp reduction in weight. One shell weighs about **11 grams.** After a few days the shell **crumbles**, and the whole shell can be turned into **powder** by hand. When grinded it becomes very fine-grained. White in color and without any scent.

At temperatures above 850 °C the calcium carbonate starts turning into calcium oxide, however I don't see any reaction with water.

HEATED AT 250°C

Cracks and crumbles a bit in the oven. Gets slightly brown outside and the nacre is burnt away. Not enough heat to burn away the biological material. The shell now weighs **25 grams**. The shell is somewhat more porous and can partly be broken into pieces by hand. The thickest part of the shell must be crushed with a hammer or similar. Some powder extracted from the process. Can be grinded into **fine powder,** but still some hard pieces won't break down . The shells have a different, sweeter and rounder smell. The powder has color variations from beige to darker brown.

RAW – DRIED AT 50-100 °C

Enough to dry out some water. Slight weight loss, the weight of the shell is **31 grams**. The shell is still hard to crush with a hammer. Very little powder extracted, **particles varying in size**.

The color of the shells and the nacreous (mother of pearl) is preserved. The powder has a gray/blue color. Still with a strong smell of the sea.

EXPERIMENTS
PACIFIC OYSTER BIOCOMPOSITES

Fifteen experiments resulting in different biocomposite materials.

Start **30.09.22**
End **10.10.22**

13

INTENTION

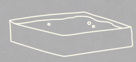
The agar agar was successful as a polymer in the bioplastic experiments, creating a soft and flexible material. Shrinking was experienced. There are many examples of alginate used as a polymer in composites, in this experiment I will test how the agar acts as a polymer in a composite material.

INGREDIENTS

- **Agar agar** 5g
- **Shell Powder 250°C**
- **Shell Particles 250°C**
- **Water** 80g
- **Sugar** 5g

PROCESS

Heat mix



Casting

Air dry

NOTES

Mix the sugar separately in water to dissolve. Mix the agar with cold water before heating the mix to avoid lumps. The material takes long time to dry completely, not dry after a week of air drying. Might need more polymer to bind the matrix. The sample bends and deforms, cracks up around the larger particles during drying. The sample is brittle and breaks when hand force is applied. Seems like tha large particles make it weaker. Adding some glycerin might make it less brittle.

14

Start **30.09.22**
End **10.10.22**

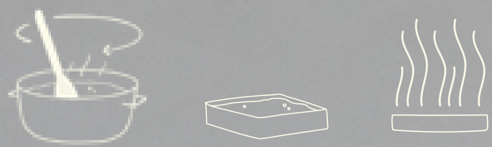
INTENTION

Testing if there is a difference in properties when only powdered shells, and less of it. A more liquid solution compared to experiment 13.

INGREDIENTS

- **Agar agar** 5g
- **Shell Powder 250°C**
- **Water** 80g
- **Sugar** 5g

PROCESS



NOTES

This sample also takes a long time to dry completely, up to two weeks. A lot of shrinkage and deformation during the drying time. This sample contains more matrix and less particles, and might shrink more due to that.The sample does not crack up the same way as sample 13, and can stand more when force is applied.

15

Start **30.09.22**
End **30.09.22**

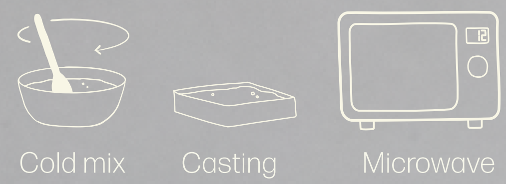
INTENTION

Testing starch as a polymer in a composite material. Did not have any success with starch in the bioplastic experiments as it never dried completely. But it was interesting in the eggshell experiment where the microwave was used for activating the binding process and drying the material.

INGREDIENTS

Potato Starch 10g | **Shell Powder 250°C** 46g | **Water** 25g

PROCESS



NOTES

The ingredients are mixed without heating. The mix is dry and needs to be pressed into the silicone mold. 3 min on medium heat in the microwave. It slightly deforms in the microwave oven. The water evaporates fast, lifting the material out of the mold, and it needs to be pressed back into mold. After 2 minutes the material is completely dry and hard. The result is a porous and brittle looking material, but with a durable surface and no broken edges or drizzling.

16

Start **04.10.22**
End **08.11.22**

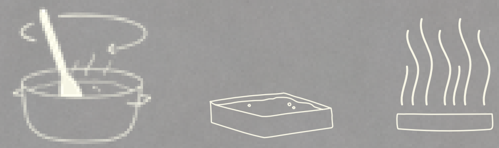
INTENTION

This sample was made ”by accident” pouring leftover gelatine solution into a mold and adding some shell powder to see if it could become a plastic-like sample. I do not have the exact amount of ingredients for this experiment.

INGREDIENTS

- Gelatine
- Shell Powder 950°C
- Water
- Salt

PROCESS



Heat mix — Casting — Air dry

NOTES

The gelatine is mixed with cold water before heating to avoid lumps. Heated for 2-3 minutes, to let some water dissolve and the gelatine becomes viscous. The result is a very thin and fragile material with no flexibility, as no glycerine was added in this experiment. The sample curls as it dries, and has one shiny side and one rough side, as the shell powder sinks to the bottom of the mold. The shell powder burned at 950, seems to absorb a lot of the water leaving a dry and ”flaky” material.

18

Start **04.10.22**
End **04.10.22**

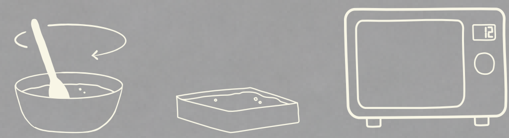
INTENTION

Testing the starch recipe from experiment 15, with shell powder burned at 950°C to see if it acts different from the shell powder burned at 250 °C. This sample is also half the thickness of the previous stretch sample to investigate if this affects the strength.

INGREDIENTS

Potato Starch 5g
Shell Powder 950°C 23g
Water 12g

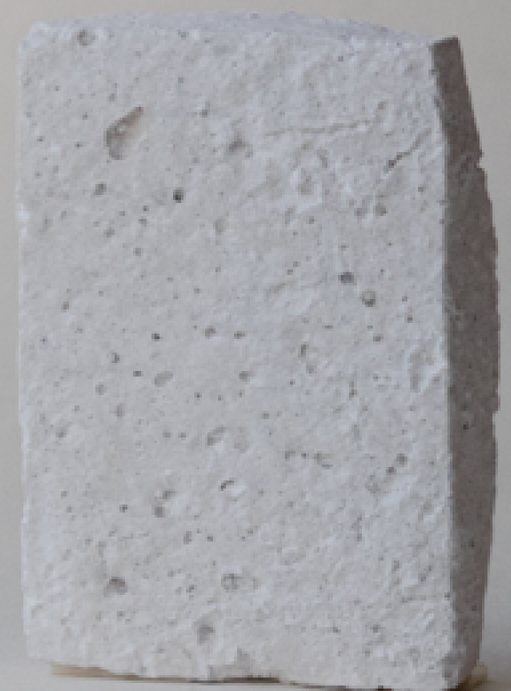
PROCESS



cold mix
Casting
Microwave

NOTES

The shell powder is mixed with the starch before cold water is added. Pressed onto a 1 cm layer on the mold, and dried in the microwave oven for 3 min at medium heat. The samples curls and deforms during the drying and I need to stop and press it back into shape. The result is a dry material that crumbles and cracks, and leaves powder. Seems like the shell powder absorbed all the water. Might need a higher amount of polymer and solvent (water).



19

Start **04.10.22**
End **04.10.22**

INTENTION

Mixing shell powder burned at 950°C and larger particles from raw oyster shells to see if it changes the properties and aesthetics of the material (from sample 18). Also testing if lower heat and longer drying time in the microwave can avoid the deformation.

INGREDIENTS

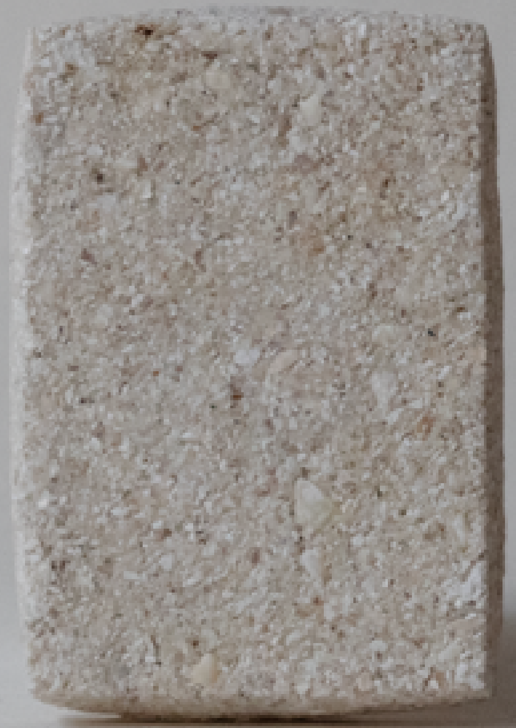
- **Potato Starch** 10g
- **Shell Powder 950°C** 35g
- **Water** 25g
- **Shell Particles Raw** 10g

PROCESS

cold mix   Casting   Microwave

NOTES

This solution was more wet and runny than the previous starch experiments with the same liquid/dry ratio. Due to the larger particles it's not absorbing as much water. As the solution is very liquid there is a lot to be evaporated, and even on a lower wattage the material cracks up a bit. The sample is more compact than the previous (18) and with large pores, probably from too rapid a process of evaporation.



20

Start **04.10.22**
End **04.10.22**

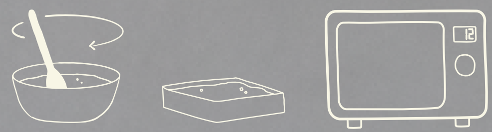
INTENTION

Adding largest particles to the mix, combining both powder and larger particles of shells burned at 250°C, to see how it affects the surface, and strength of the material. Also testing a solution with less water, due to the larger particles.

INGREDIENTS

- **Potato Starch** 10g
- **Shell Powder 250°C** 20g
- **Water** 20g
- **Shell Particles 250°C** 26g

PROCESS



NOTES

Can clearly see a difference in the surface of the sample. The different sized particles are visible and create a more textured expression, and color variations. Difficult to say if it affects the strength without testing it properly. The sample also feels heavier than sample 15.

21

Start **10.10.22**
End **12.10.22**

INTENTION

Mixing the shell powder burned at 250°C and 950°C, to see how it changes the properties. Experimenting with adding more water to the solution in order to make it more liquid and possible to pour into the mold without compressiong it. Leave to air dry before "activating" the starch polymer in the microwave oven.

INGREDIENTS

Potato Starch 15g | **Shell Powder 950°C** 20g | **Water** 40g | **Shell Particles, 250°C** 26g

PROCESS

NOTES

The liquid solution can easily be poured into the mold. After 5-6 hours of air drying the sample is completely dry and hard, with sharp edges. Has an even and smooth surface ,beige/yellow colour. Can't see any difference after microwave.

22

Start **18.10.22**
End **20.10.22**

INTENTION Testing there is a difference when heating the starch mix before casting it. Leave it to air dry, and check if the starch binder has been "activated" sufficiently, or if a microwave is needed.

INGREDIENTS

- **Potato Starch** 15g
- **Shell Powder 950°C** 20g
- **Water** 40g
- **Shell Particles, 250°C** 10g

PROCESS

NOTES The mix quickly turns viscous and thick. Hard to pour into the mold, almost like glue. Dries quickly without the need for a microwave. Deforms when dry.

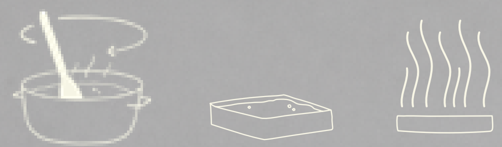
23

Start **10.10.22**
End **12.11.22**

INTENTION Exploring how gelatine can act as a polymer in the composite material. Testing with more liquid than particles to recreate the process of sample 12, where the particles sank to the bottom of the mold creating a compact material, and with the excess gelatine on top.

INGREDIENTS **Gelatine** 10g | **Water** 40g | **Glycerine** 3g | **Shell Powder 250°C** 15g

PROCESS



NOTES The sample is dry enough to take out of the mold after 5-6 hours. All the gelatin floats to the top creating a thick layer. The shell particles fall to the bottom. Cut off the excess gelatin, continue dry under pressure to avoid deformation. The sample has a smooth sanding paper-like surface, with color variation from beige to dark brown.

24

Start **10.10.22**
End **16.11.22**

INTENTION

This experiment was aiming to create a thin plastic like material, exploring how the shell particles can be used in a bioplastic, where the shells are used more as an aesthetic element.

INGREDIENTS

Gelatine 5g | **Water** 20g | **Glycerine** 2g | **Shell Powder 250°C** 5g

PROCESS

NOTES

There is a larger amount of liquid (water) in this sample and less particles, and the drying time is long - almost a week. The result is a thin and very brittle material. The material is semi-transparent with a yellow color and visible grains of the shells. A thicker sample with even more particles encapsulated inside would be interesting. also to test if it can become more flexible by adding more glycerin and how the particles will act then.

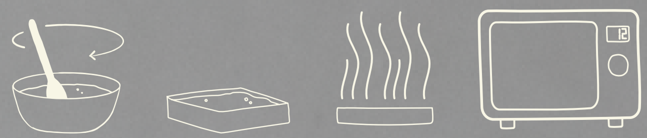
26

Start **18.10.22**
End **20.10.22**

INTENTION Testing if there is a difference in the properties using cornstarch in comparison to potato starch. The recipe is the same as experiment 21. Check if there is any heat produced during the air drying time, is there a reaction with the shells burned at 950°C and the water? What is the effect of the microwave after air drying?

INGREDIENTS **Corn Starch** 12g | **Shell Powder 250°C** 26g | **Water** 40g | **Shell Particles 250°C** 20g

PROCESS



Cold mix — Casting — Air dry — Microwave

NOTES The sample dried for 1,5 days. Broke into pieces when taken out of mold. The result is very porous and fragile material. Similar appearance to sample 21, but releases powder when handled.

27

Start 18.10.22
End 01.11.22

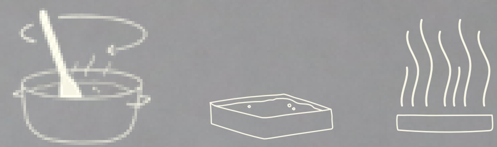
INTENTION

Experimenting with a thicker material/composite layer. Adding glycerine to the solution, to see if it will become less brittle, and stand more. Only using raw oyster shells for å different appearance.

INGREDIENTS

- Gelatine 15g
- Shell Powder Raw 20g
- Shell Particles Raw 20g
- Glycerine 7g
- Water 40g

PROCESS



NOTES

The material applied pressure during drying to stay flat. Can be taken out of the mold after a short time, but takes two weeks to dry properly. Changes a lot, during drying leaving a rough surface and slight bends. The material seems very durable.

28

Start **18.10.22**
End **20.10.22**

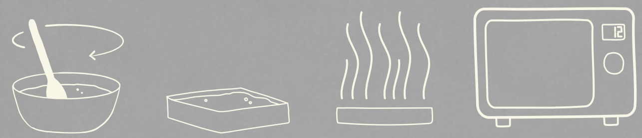
INTENTION

Testing with larger particles, both to test if it changes the properties, and experimenting with a different appearance. Adding a bit more potato starch, and using a mix of Shell Powder burned at 950°C, and raw powder.

INGREDIENTS

- **Potato Starch** 15g
- **Shell Particles, raw** 10g
- **Water** 40g
- **Shell Powder 950°C** 20g

PROCESS



NOTES

The sample air dried for 1,5 days. The larger particles are visible on all sides of the sample, with a porous look. However, not too much loose powder. After 2 minutes in the microwave oven there was no deformation to the sample.

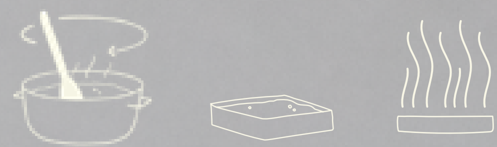
Start 19.10.22
End 02.11.22

30

INTENTION Same recipe as 27, with less glycerine. Using only shells burned at 250°C, to explore the aesthetic differences.

INGREDIENTS Gelatine 15g | Shell Powder 250°C 20g | Shell Particles 250°C 20g | Glycerine 4g | Water 40g

PROCESS



Heat mix Casting Air dry

NOTES Same drying process as experiments 27. A very different appearance with a warm beige color, when only using the shells heated at 250 °C. The gelatine matrix and combination of particles and powder creates a very strong material.

OYSTERWORKS

A material driven design project exploring the potential of The Pacific Oyster in biomaterials.

Hanna Tørstad
Diploma Project – Fall 2022
The Oslo School of Architecture and Design