Bioma

Biomaterials Exploration

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The Problem

The use of plastics and unsustainable materials is polluting our earth and having irreversable effects on the environment. Single use plastics and household goods take thousands of years to break down in landfills and are releasing toxins that harm humans, animals, and the earth.

Our systems for manufacturing, distributing, using, and disposing of products needs to change.

(Not So) Sustainable Alternatives

While many companies claim to be solving the waste crisis, many existing material alternatives aren't actually better for the environment.

Commercial Bioplastics

New compostable bioplastics claim to be more sustainable, but require intense industrial processes and facilities to be broken down. Many are still made with some traditional petroleum plastic.

Reusable bags

As an alternative to plastic grocery bags, reusable bags require more plastic during their lifetime on average. The intensive process required to make cotton bags also has an adverse effect on the environment.

Bamboo and hemp composites

Bamboo and hemp are touted as plastic alternatives, but the composites are made with traditional plastics and will not break down without an industrial process.

The recycling industry

Our recycling infrastructure can't keep up with the amount of plastic being thrown out, and companies aren't willing to front the cost. The United States only recycles 10% of its plastic waste.

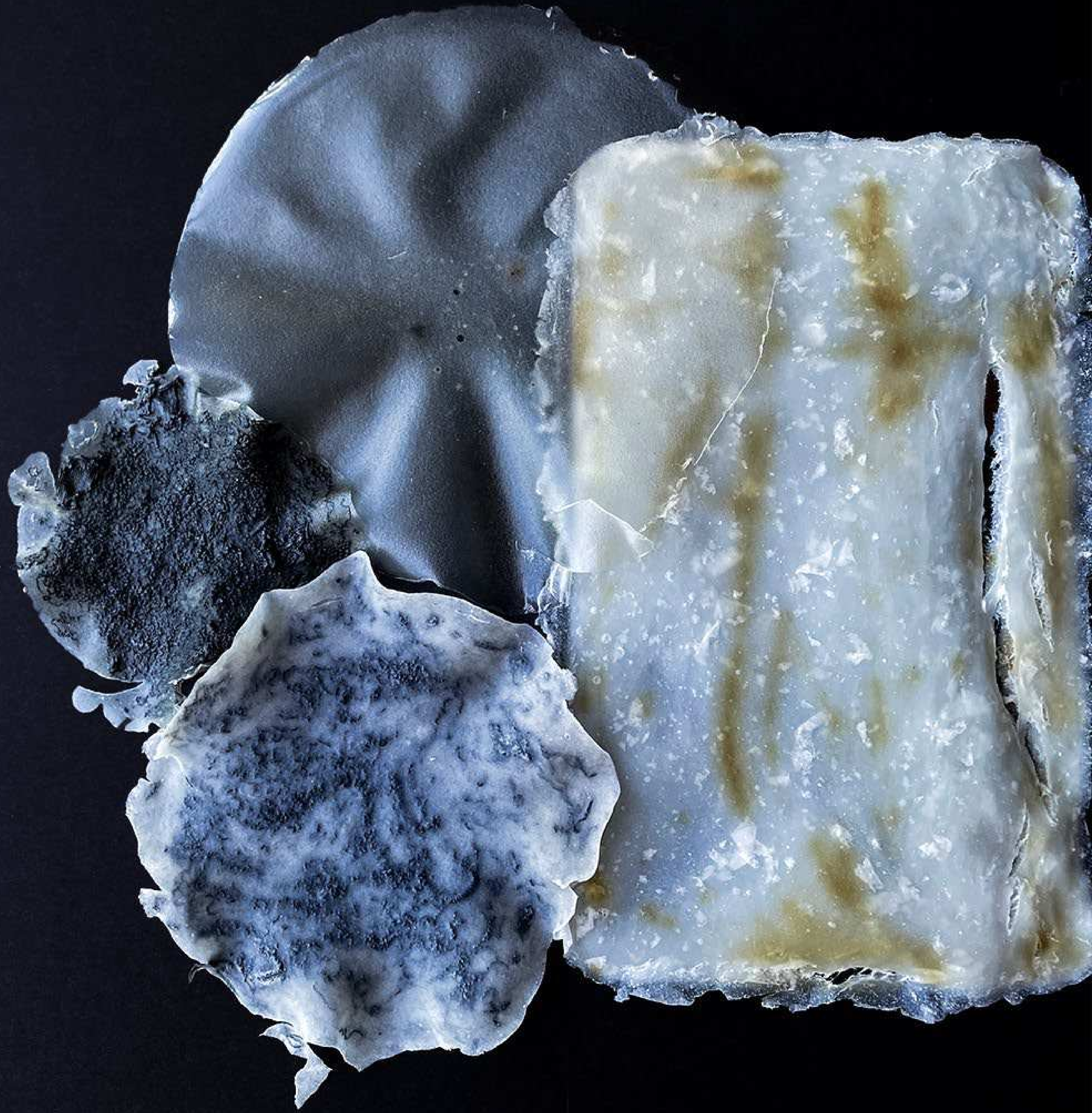
Project Goals

Test materials material alternatives that are entirely natural and biodegradable.

Explore materiality and properties to create new product solutions.

Form a deeper connection with the materials and waste we create by handmaking product alternatives

Material Testing



Testing Ingredients

Agar-agar

A gelatin-like substance made from algae that is used in food, cosmetics, and microbiology.

Cornstarch

A corn-based starch that is used for thickening in food as well as adhesives, paper, textiles, and to creat non-newtonian fluids.

Cellulose

A component of plant walls that is used in paper, cardboard, and textiles.

Cotton fibers

Cotton is a natural and biodegradable fabric and there is opportunity to use the large amount of fashion waste generated.

Bamboo

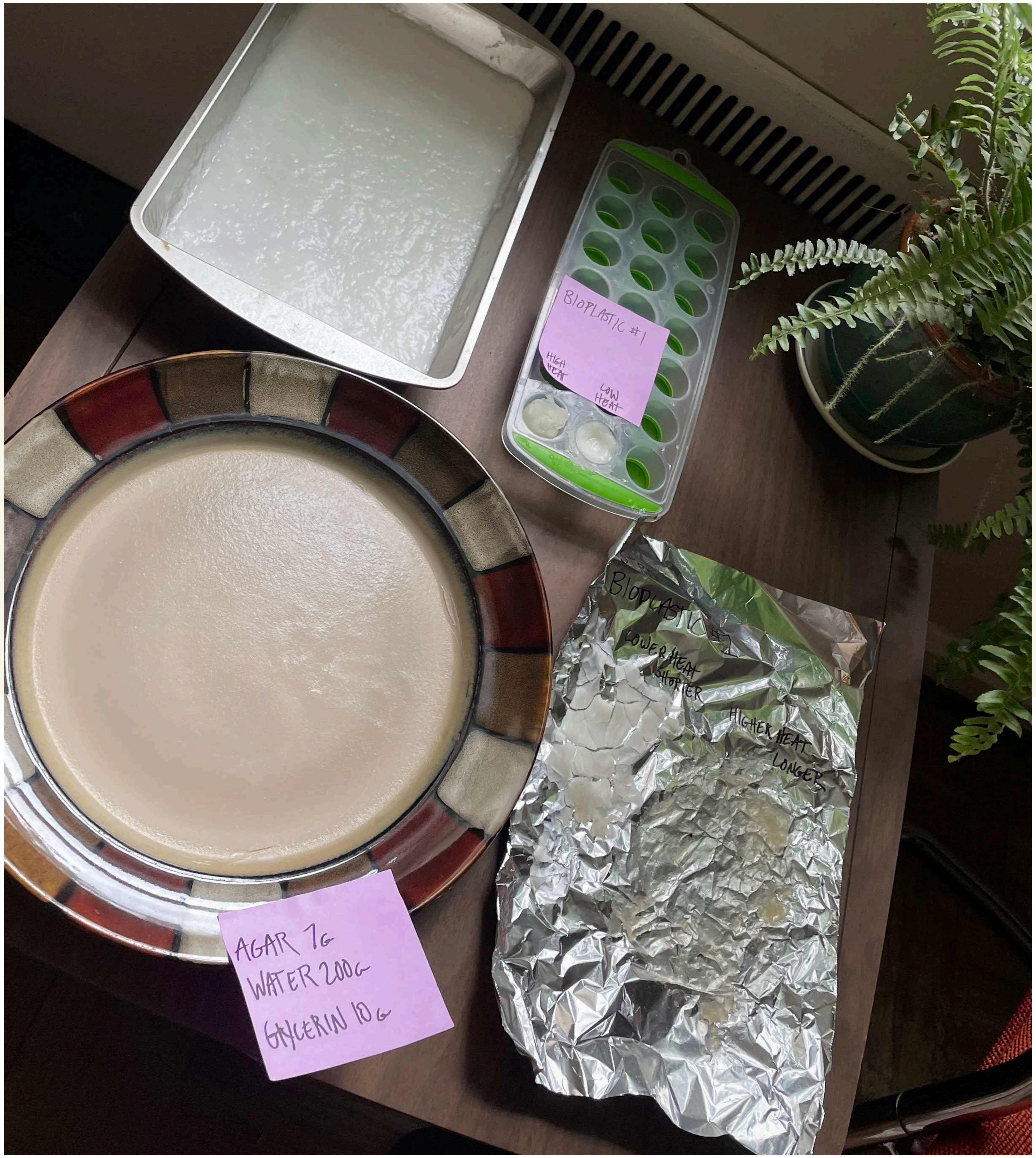
A fast-growing and commonly available plant that can be used in construction, composites, and textiles.

Glycerine

A.K.A glycerol, naturally occuring alcohol that attracts water molecules. Used in cosmetics, medicine, and food. Makes materials more flexible.

Basic Recipes

I found these existing recipes through research and will test them to get a basis for different directions moving forward.



Recipe 1: Cornstarch Bioplastic

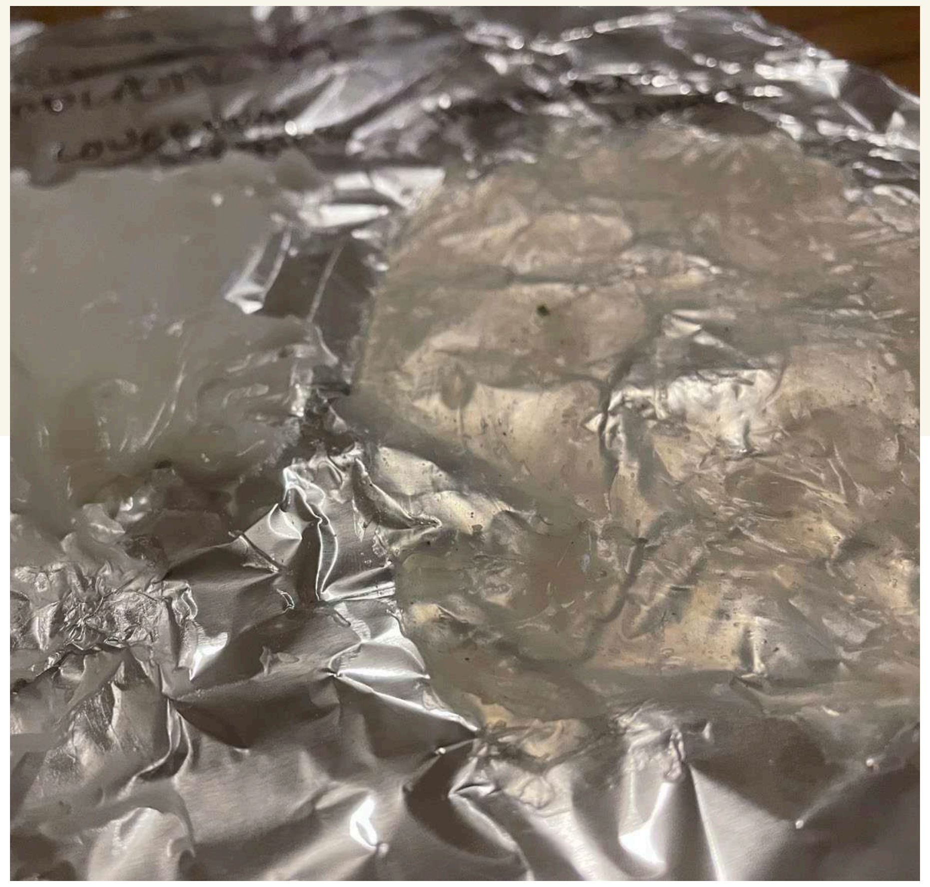
Ingredients:

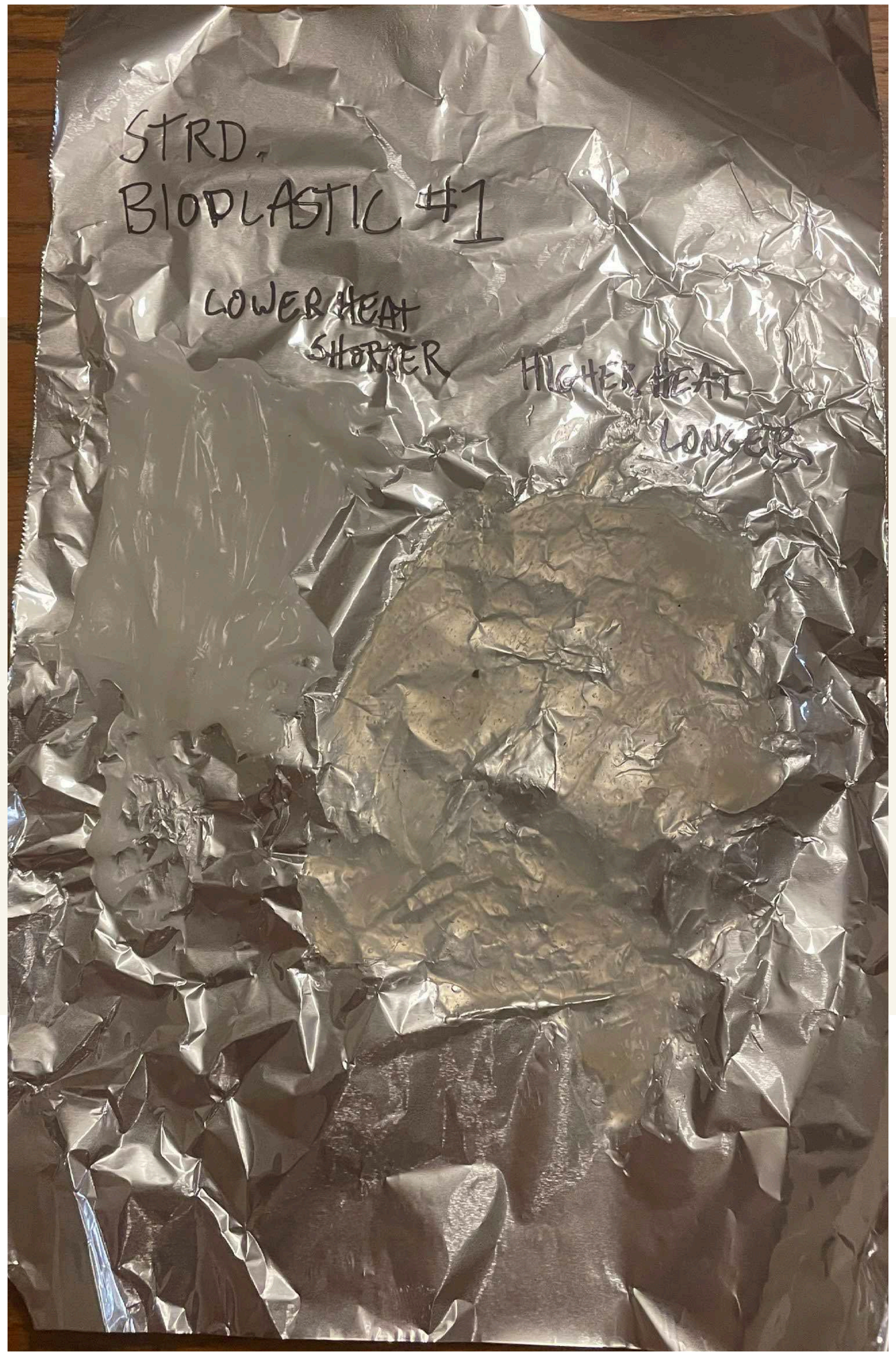
10 ml water

1 g glycerol

1.5 ml white vinegar

Ingredients are mixed together cold and heated in pan over medium-low heat. Within 5-10 minutes the mixture thickens and becomes translucent.



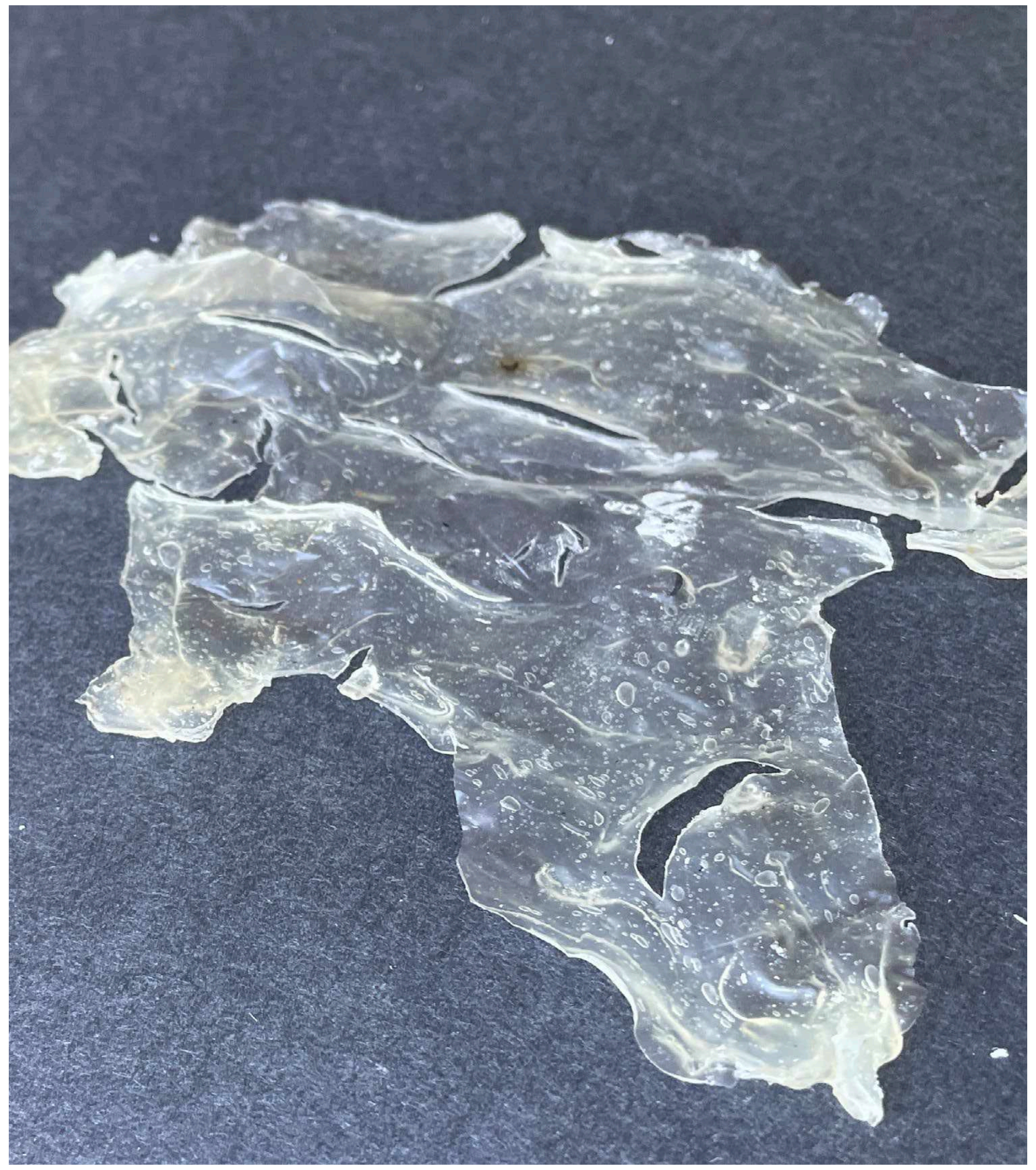


2 tests were done, one at higher heat and becoming thicker and the other at lower heat and not thickening as much. Both tests were poured in small mold and spread flat onto foil

Higher heat is more firm and quicker drying, but is harder to work with and does not pour easily. Lower heat is much less firm.

Recipe 1: Cornstarch Bioplastic






This material was not very successful. It is soft and brittle, crumbling easily both during the drying process and while handling when dry. This problem is evident both when molded and dried flat.

Recipe 2: Agar Bioplastic

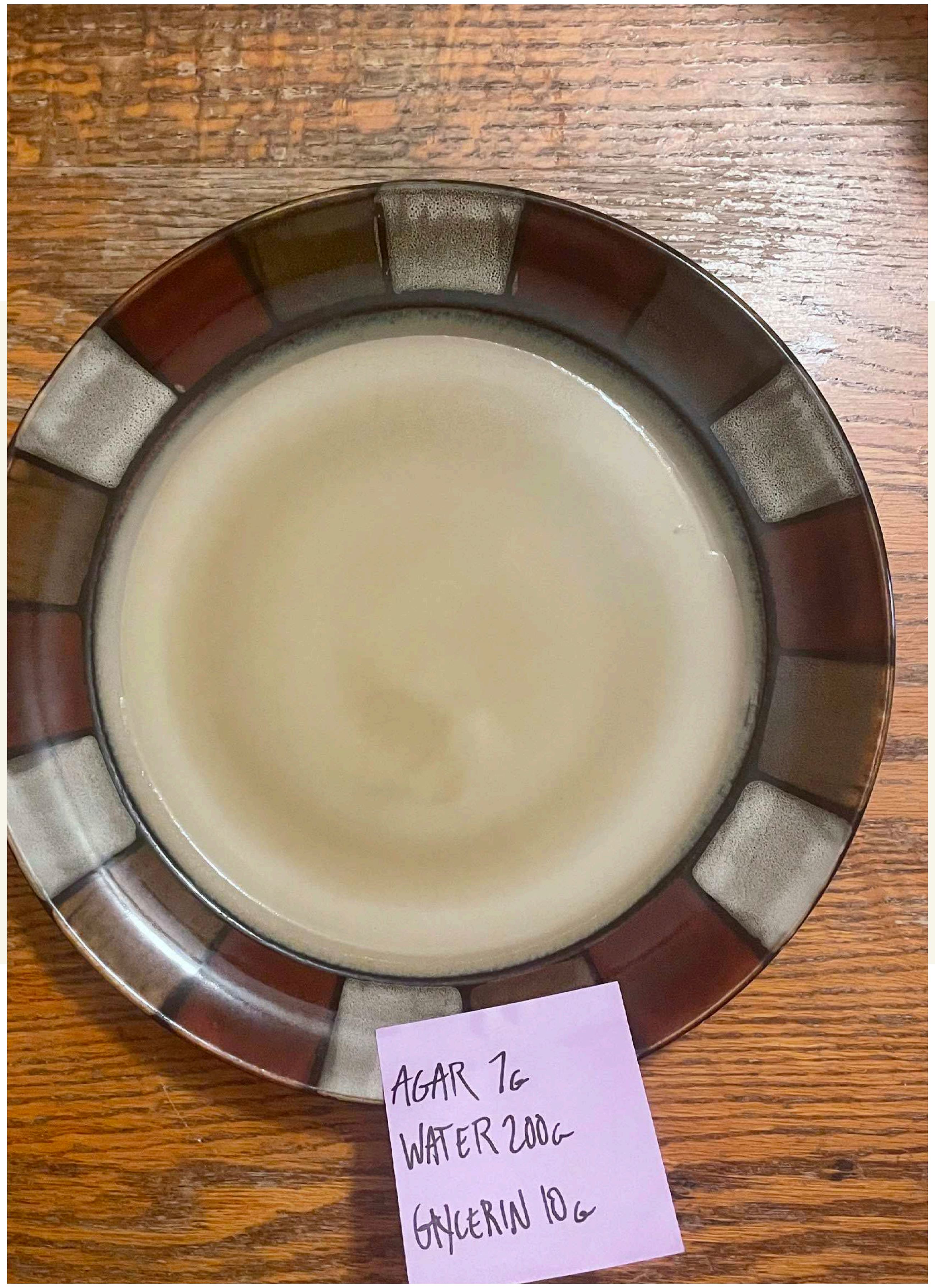
Ingredients:

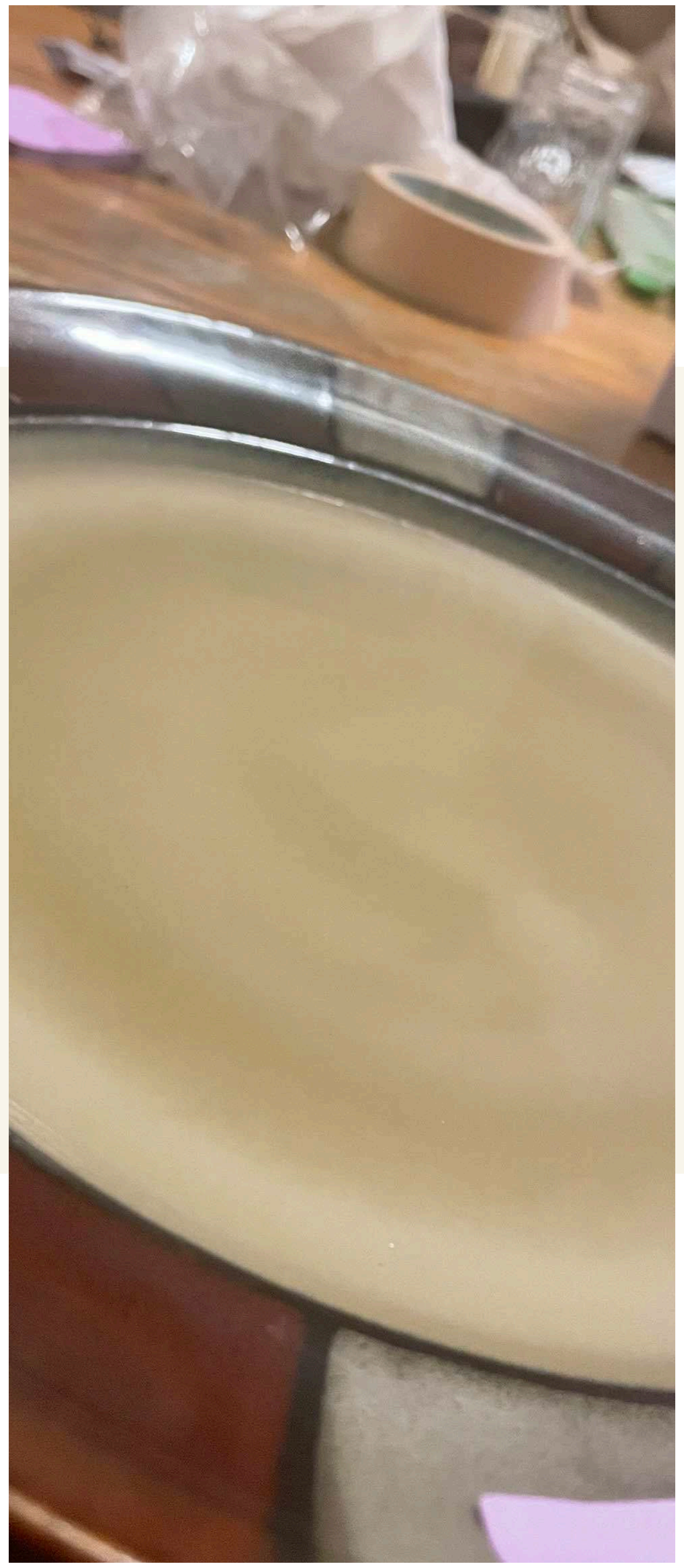
200 ml water

7 g agar

10 g glycerol

Agar and water mixed together cold.
Mixture is heated, glycerol added.
Mixture is heated for around 10 minutes until it becomes gelatonous .

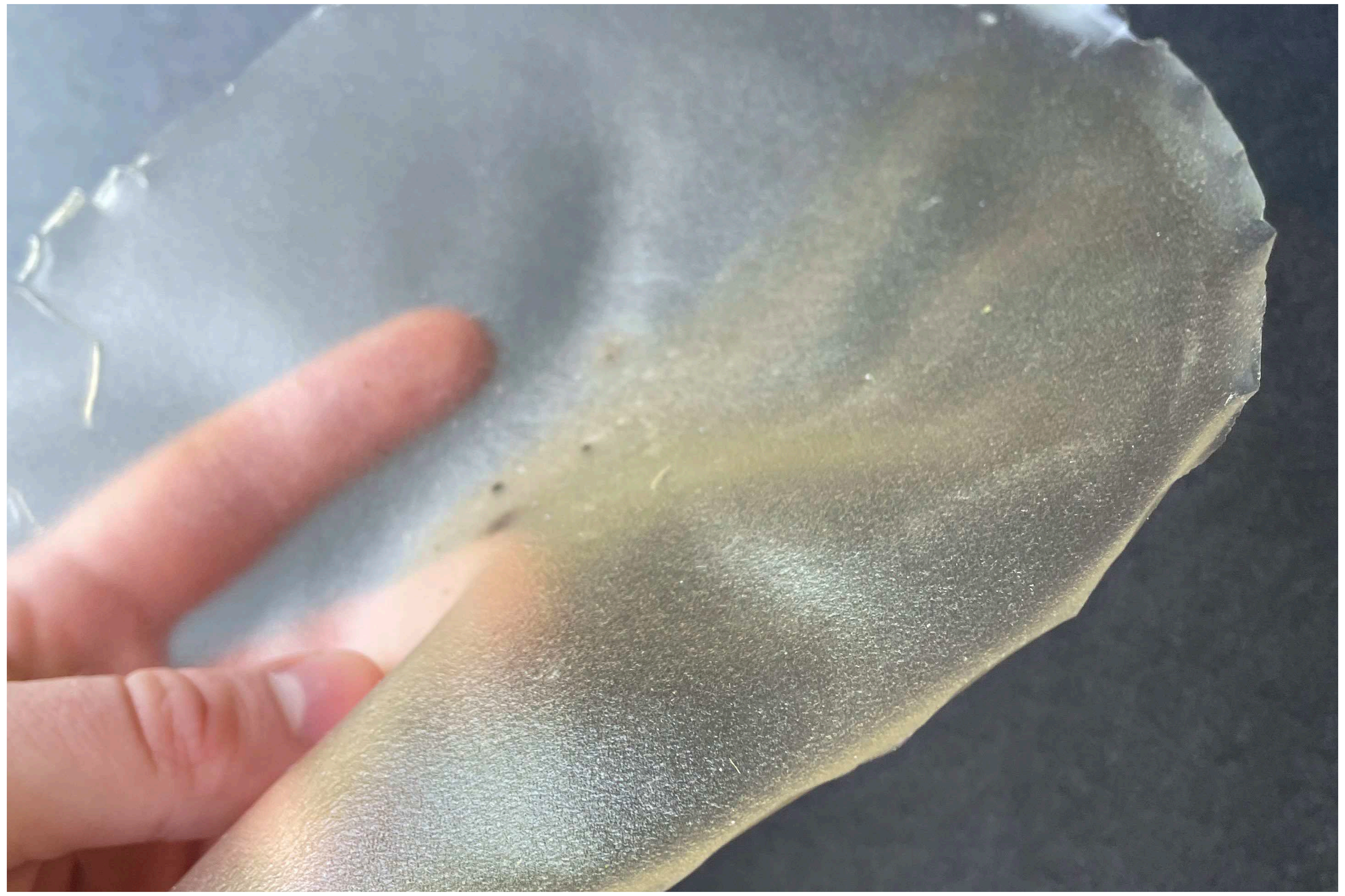




Mixture poured into shallow plate as mold. The material is almost completely clear and quickly firms up

Texture is gelatin-like and smooth

Recipe 2: Agar Bioplastic



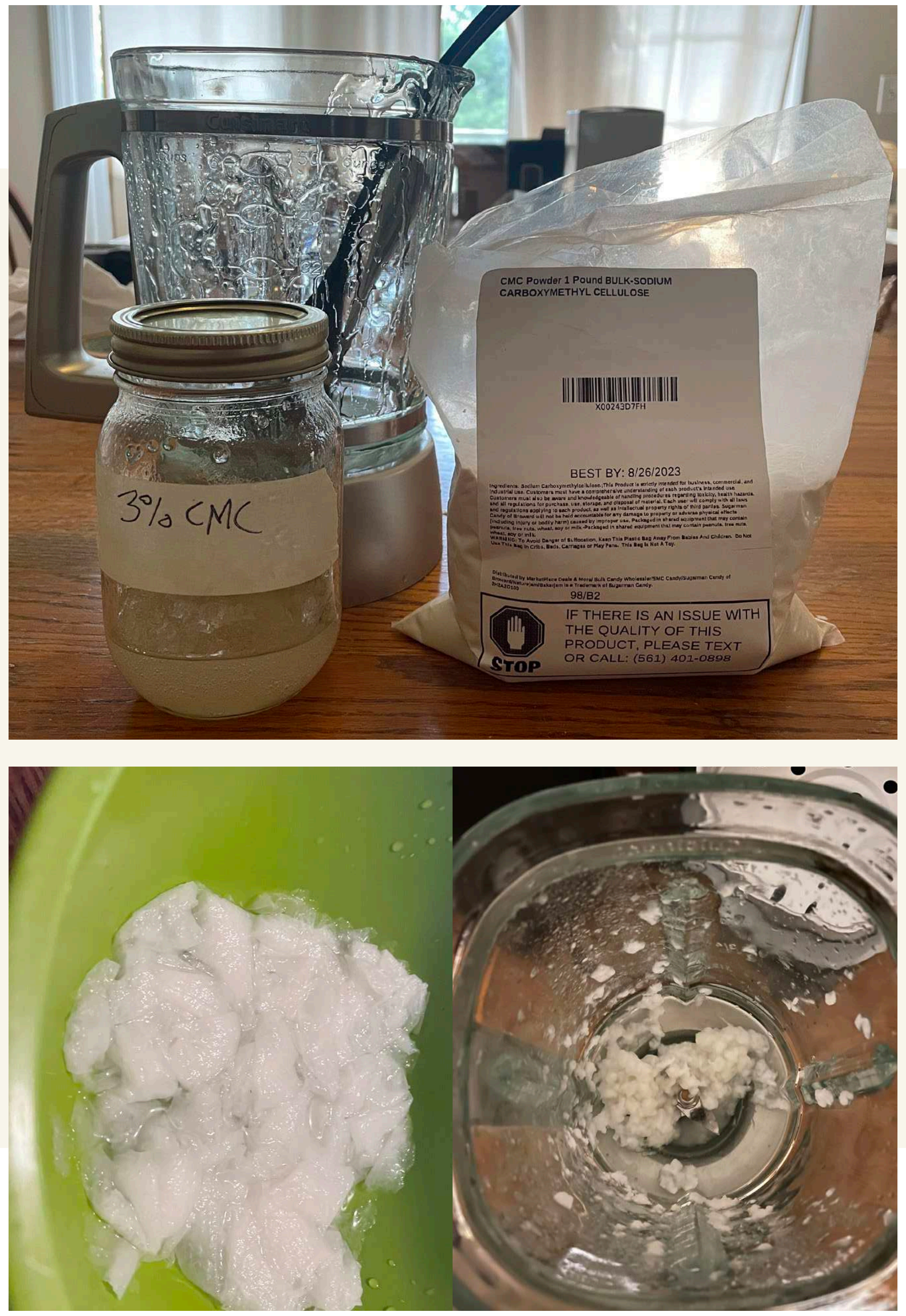
This material was successful, and very simple. The material is fairly strong and pliable. It dried enough to become workable a lot more quickly, within 2 days. After a week and a half, almost all the moisture is gone and the material is very thin.

Some mold formed during drying, once it is workable it should be lifted to allow more airflow. Adding moreglycerol could add even more body and flexibility.

Recipe 3: Cellulose Leather

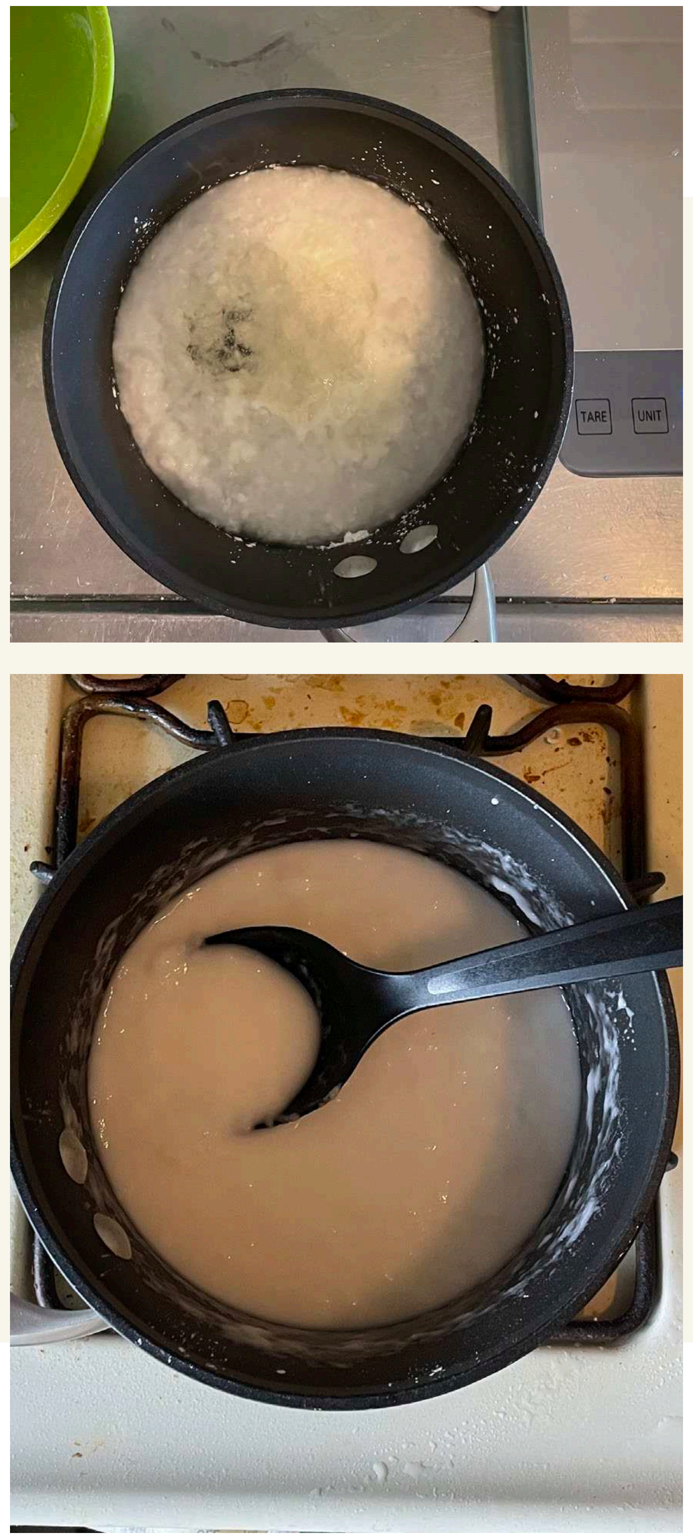
Ingredients:

100 ml water
5 g pulp
130 g microcrystalline cellulose (MCC)
30 ml carboxymethyl cellulose (CMC) 3% water solution
35 ml glycerol
20 g corn starch
5 ml vinegar



Prep: CMC 3% solution is made by blending with water, sitting overnight until thick.

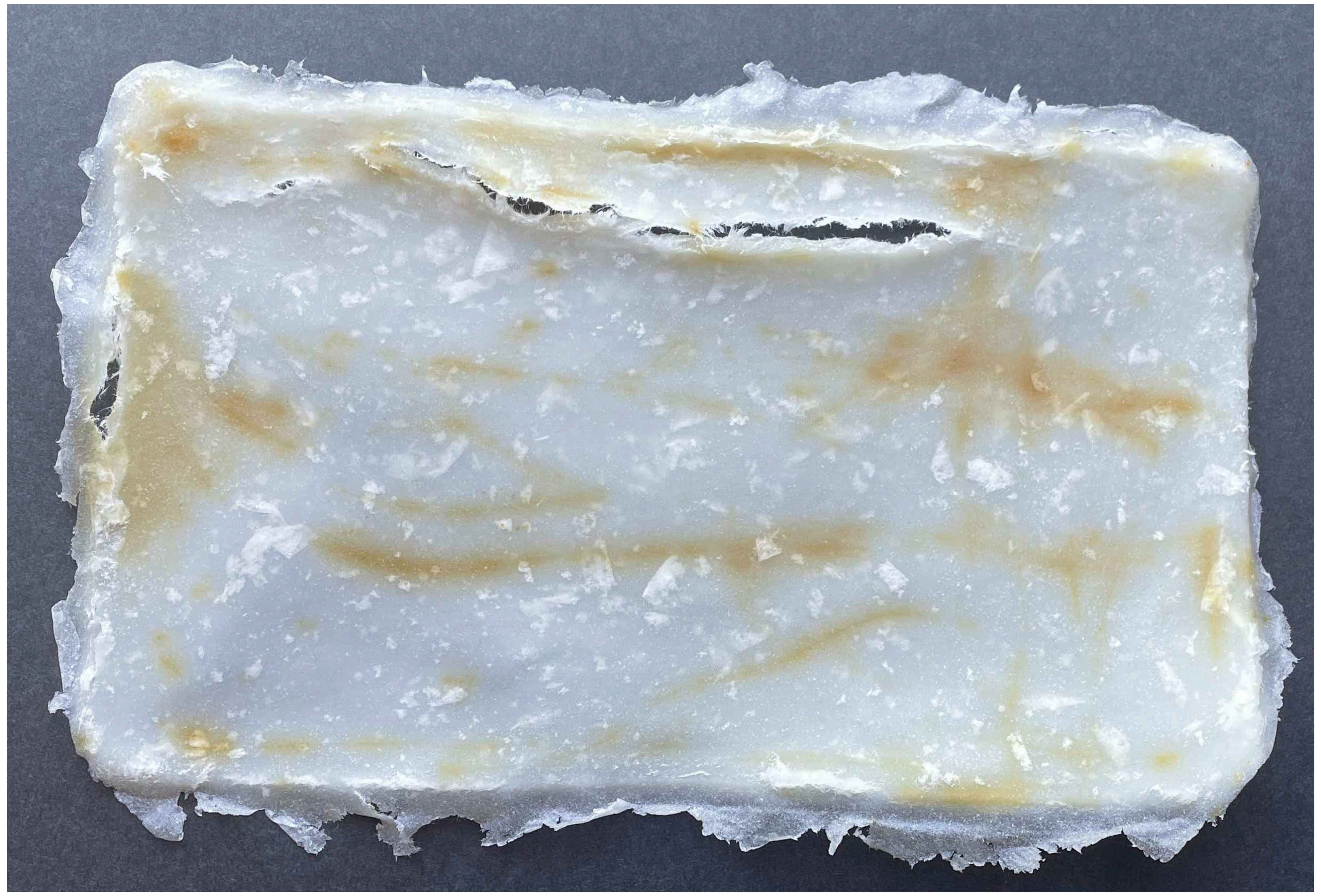
Pulp is made from paper towel waste blended with water.



All ingredients mixed and heated slowly until bubbles begin to form.

Mixture poured at around 5mm thickness and dried for 5 days.

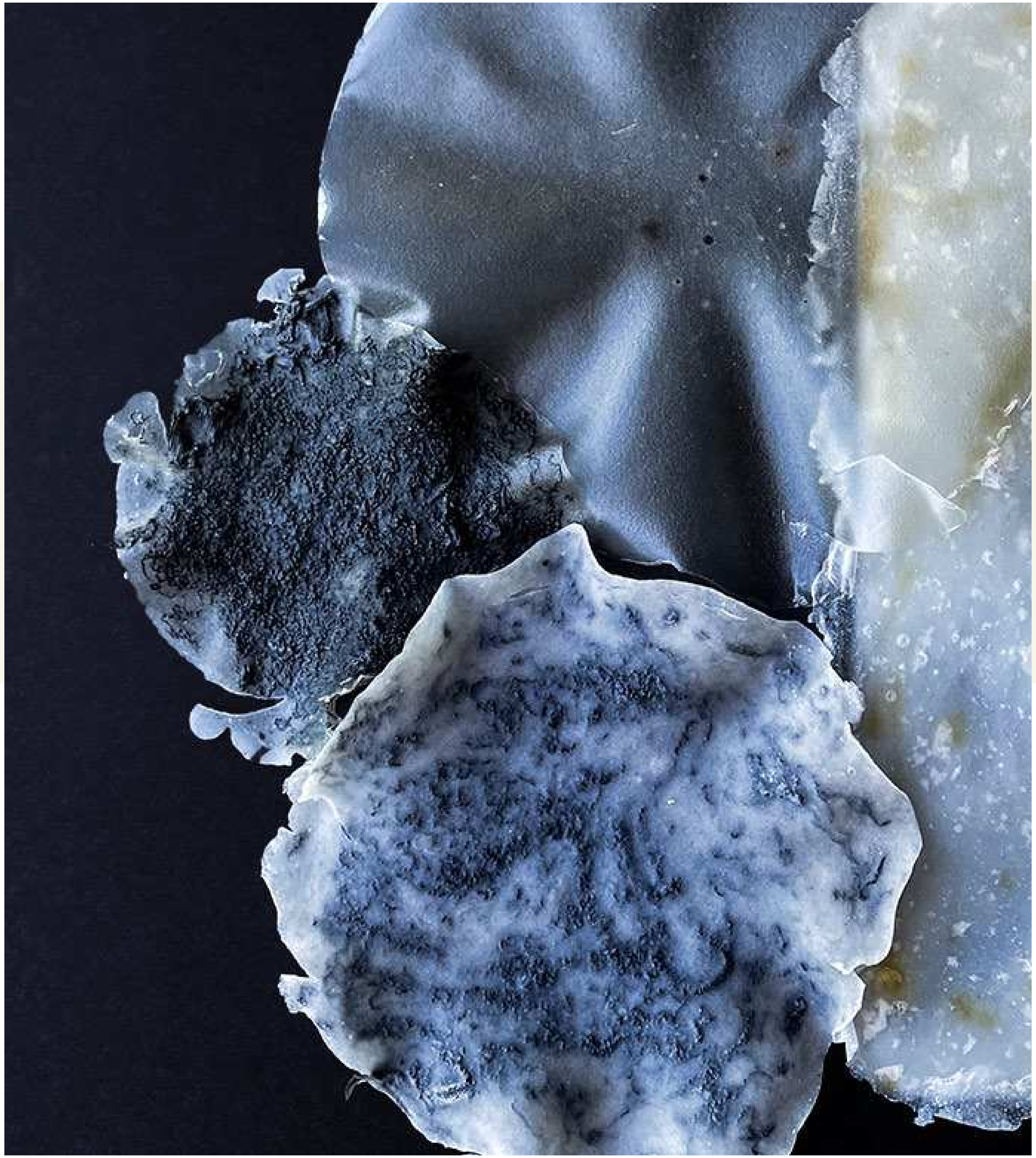
Recipe 3: Cellulose Leather



This recipe was overall very successful. The leather is fairly strong and pliable with a little elasticity. The material does take a while to dry, almost a week. There was a tear in the material while drying due to the shrinking while the water evaporates out.

Further Exploration

With the success of agar and cellulose recipes, I expand on these materials by tweaking the ingredients and using them to create composites.



Agar Foam

Made by adding dish soap to agar bioplastic and whipping to make a foam.



This material was not very successful. It takes a while to dry, and does not offer any strength or flexibility. The material is very brittle and fragile, crumbling during the drying process. It can also not be handled without breaking.

Chitosan Material

Chitosan is derived from the exoskeletons of shellfish and is one of the most abundant materials in the world.

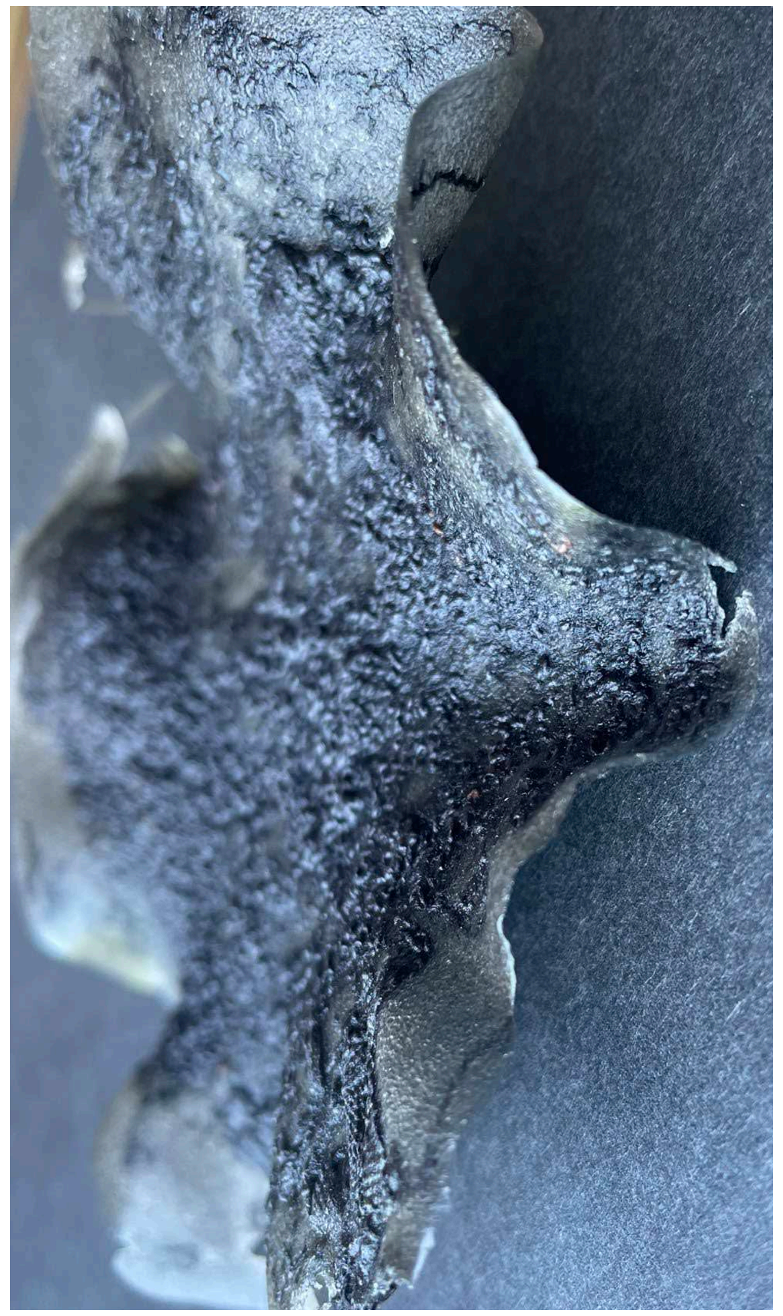
I combined chitosan powder with water and glycerin and heated the mixture. It was unsuccessful. The material is powdery, dry, and crumbly. It shrunk and broke apart during the drying process.

Agar + Cotton Fiber

Building off the success of agar, I added glycerin for more flexability and fibers for more strength.



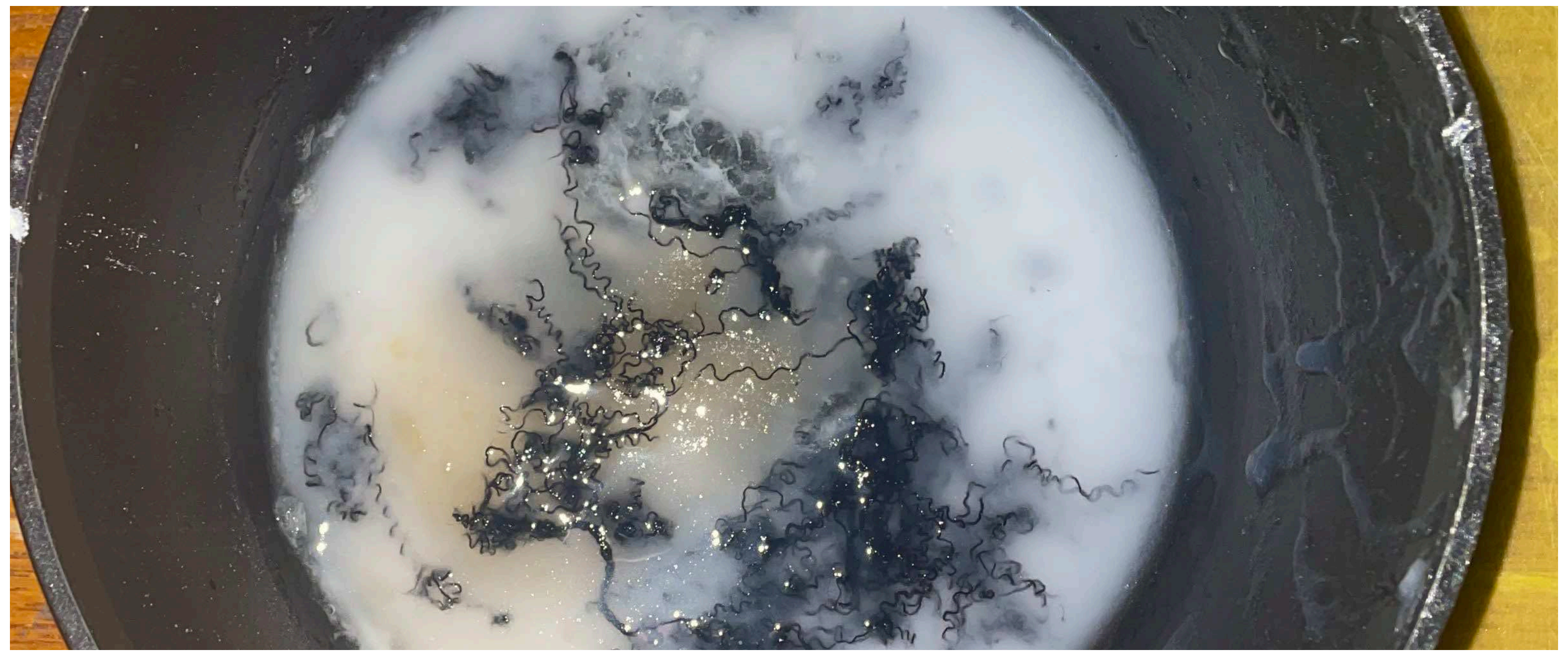


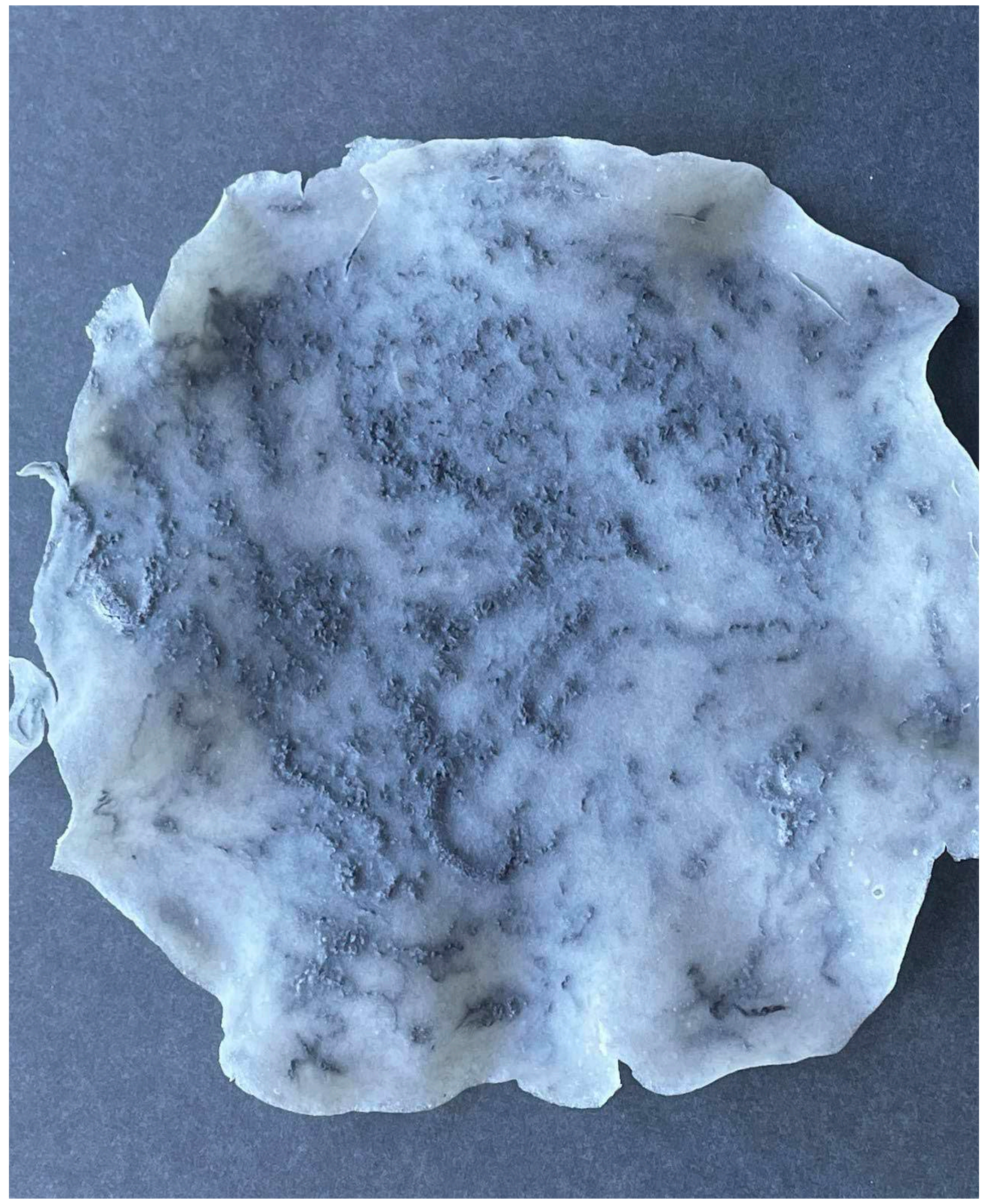
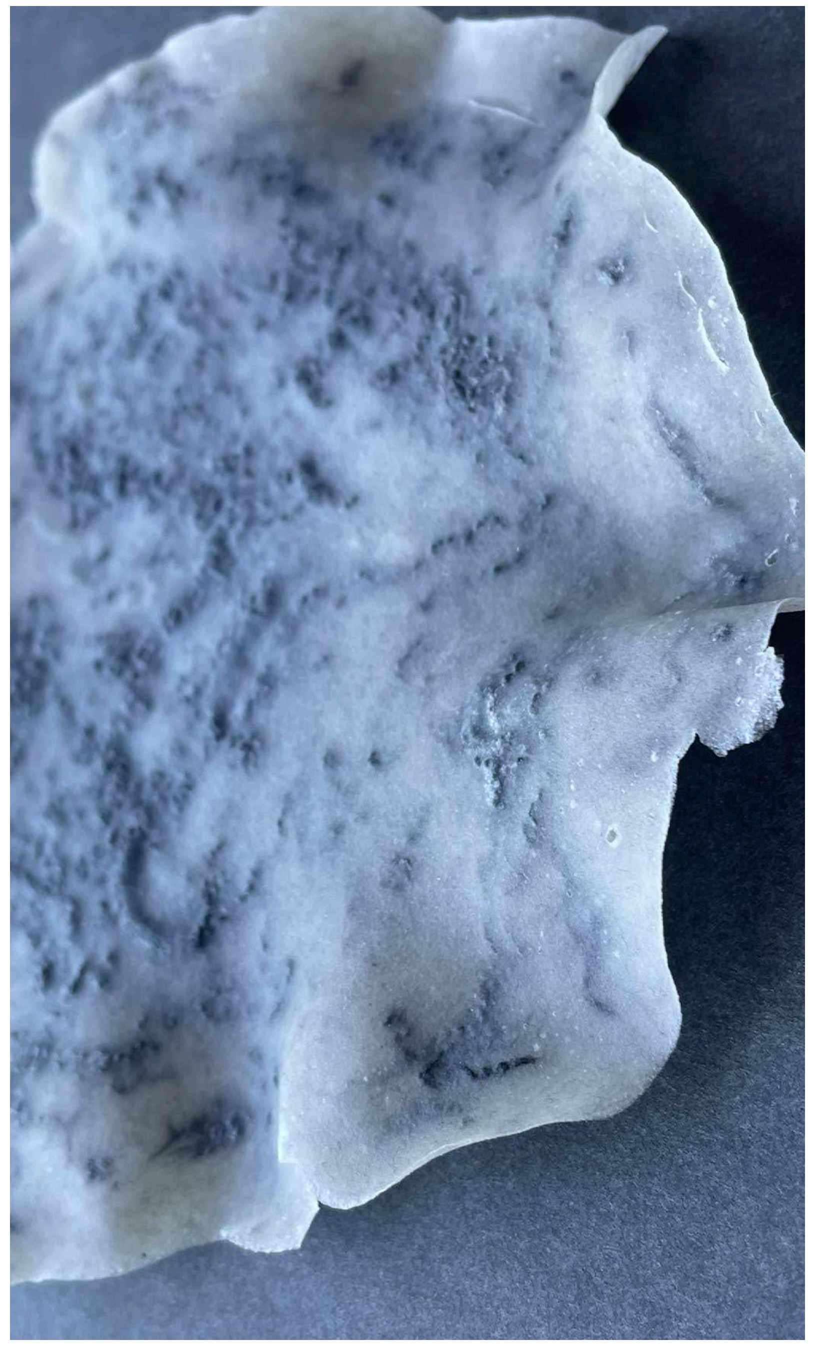


This material was successful. It is harder than previous materials but still flexible and strong. The material curled when drying but could be flattened. There were clumping issues with the cotton fibers but they were still able to be spread fairly evenly.

Cellulose + Agar + Cotton Fiber

Adapted from the cellulose leather, with cornstarch replaced with agar and added cotton fiber

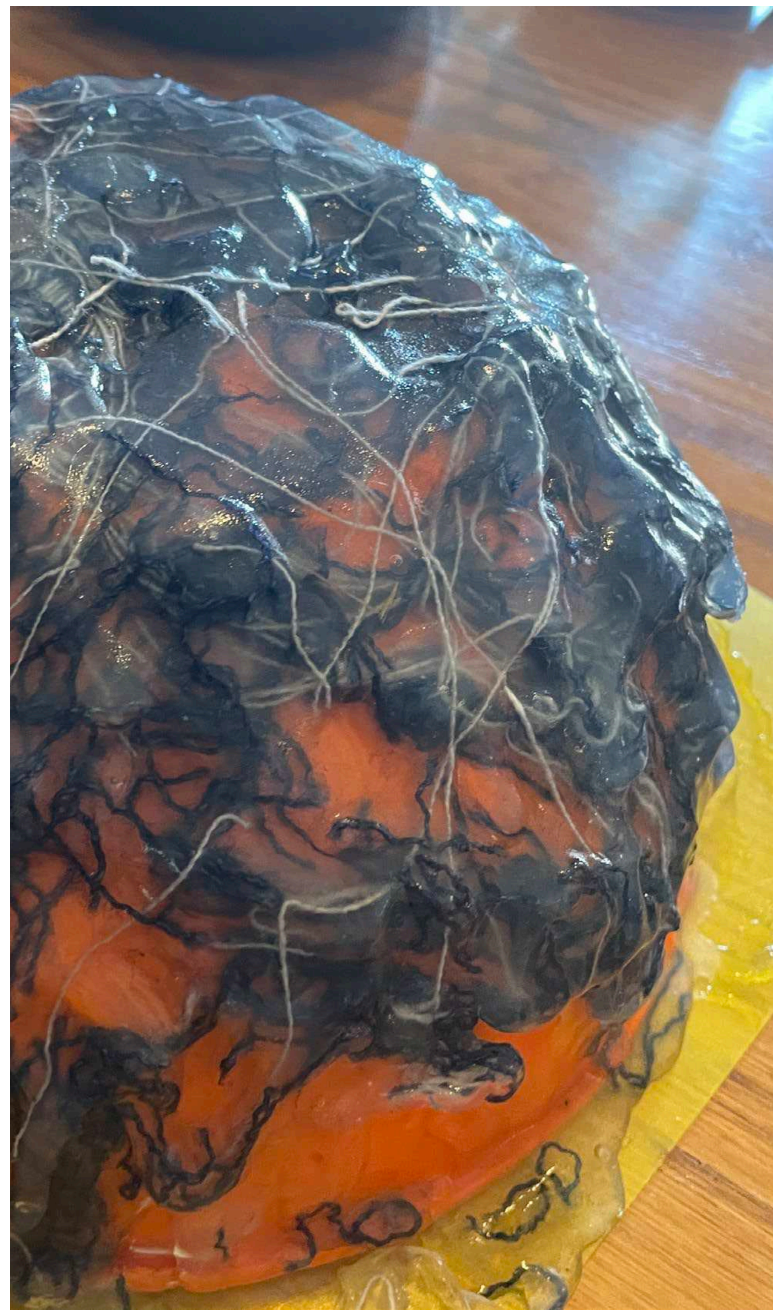



This material was successful. It has a similar soft feel to the previous cellulose leather, but is more elastic and pliable. It dries much quicker thanks to the addition of agar. The cotton fibers distribute stress more evenly along the material and there were no cracking problems. It does have similar curling to the previous agar material.

Agar + Denim Fiber

Agar bioplastic with fiber from denim waste



Using scrap denim, I seperated the fibers. There are much thicker and sturdier than the cotton T-shirt fibers I used. I tested a composite with the agar plastic poured over the outside of a round form to see how it shirnks and curls around it.

Plaster Molding

I made a few plaster molds to test the materials. Plaster is porous and draws out moisture from the composites while they are drying.

The first mold test I did was using my standard agar recipe as a thin film over a curved mold to see how it holds a shape. The material shrunk but held a form and was more sturdy than plastic wrap.

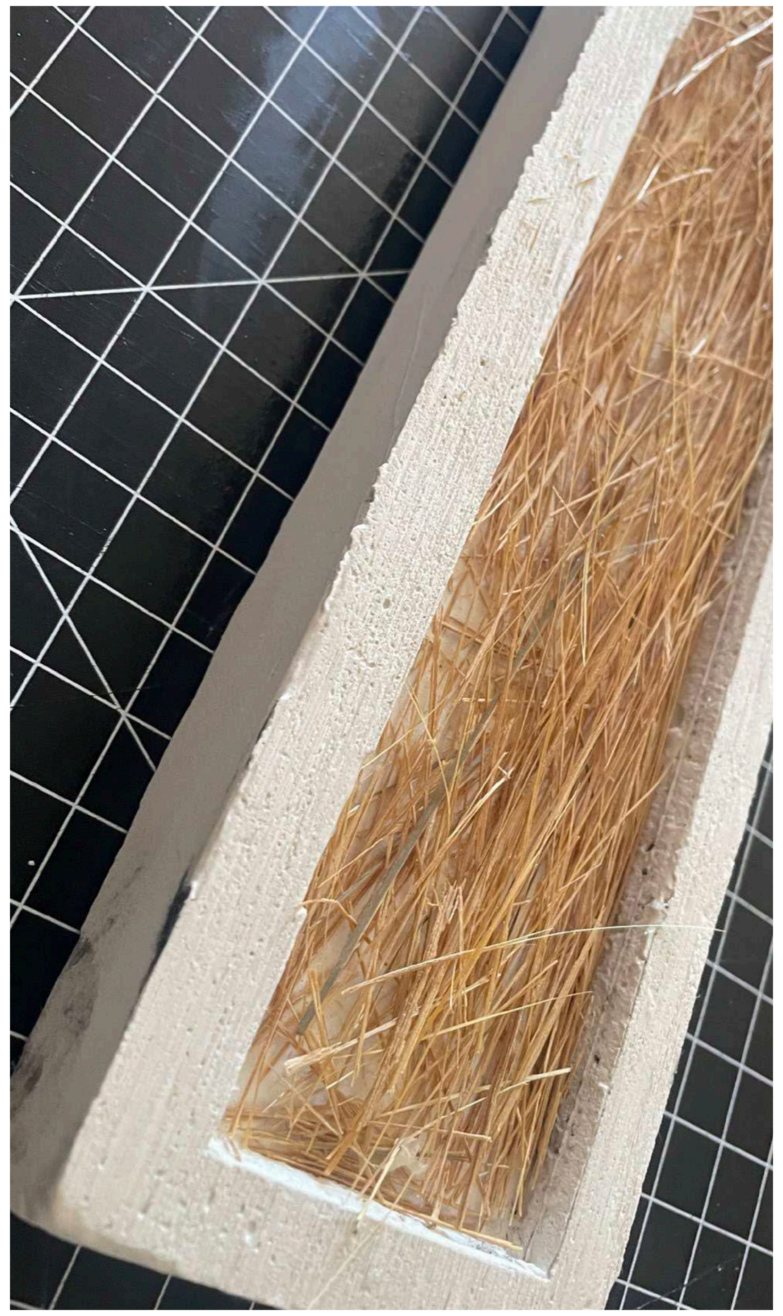
Bamboo

Bamboo is a unique material with many applications. It is also fast-growing and commonly available, and is an invasive species in the U.S.

To prepare the bamboo, the stalks are dried in the oven and then soaked in lye to break them down into fibers.

Agar + Bamboo Fiber

Bamboo fibers are broken down to around 1-3 inches in length and layed along mold. Aagr bioplastic is poured over the fibers.






The material is flexible and very strong. The agar shrinks around the bamboo fibers while they minimize the overall shrinking of the material. It can be bent without snapping or tearing.

Agar + Fine Bamboo Composite

The bamboo is ground to a powder and mixed with water to create a pulpy mixture. This solution is then used in the agar bioplastic recipe.




When dried, this material is very rigid and hard. This is a successful breakthrough in finding a material that has some of the rigid properties of plastic. It is somewhat easy to snap when thin and has some curling and shrinking issues.

Agar + Fine Bamboo Composite

I further tested this material in a larger and thicker form factor to see if it retains its rigidity and how it shrinks throughout the drying process.

The material is still drying, but has already shrunk considerably. While drying, it has a more gelatinous feel and is more plyable. So far it has retained its overall form very will with minimal curling or warping.

Natural Dye

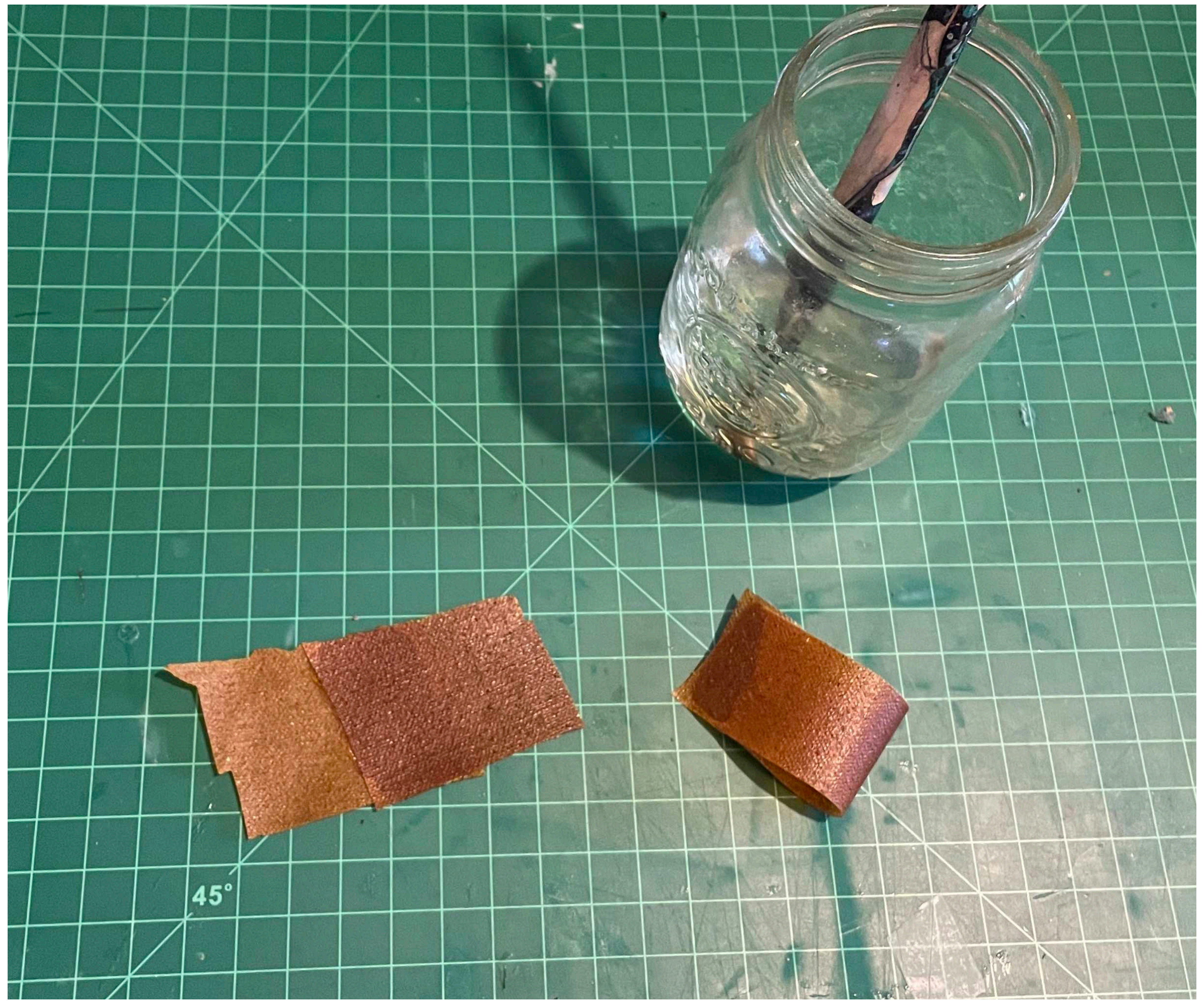
To improve the appearance of the materials, I extracted dyes from common food products and waste that is commonly available.

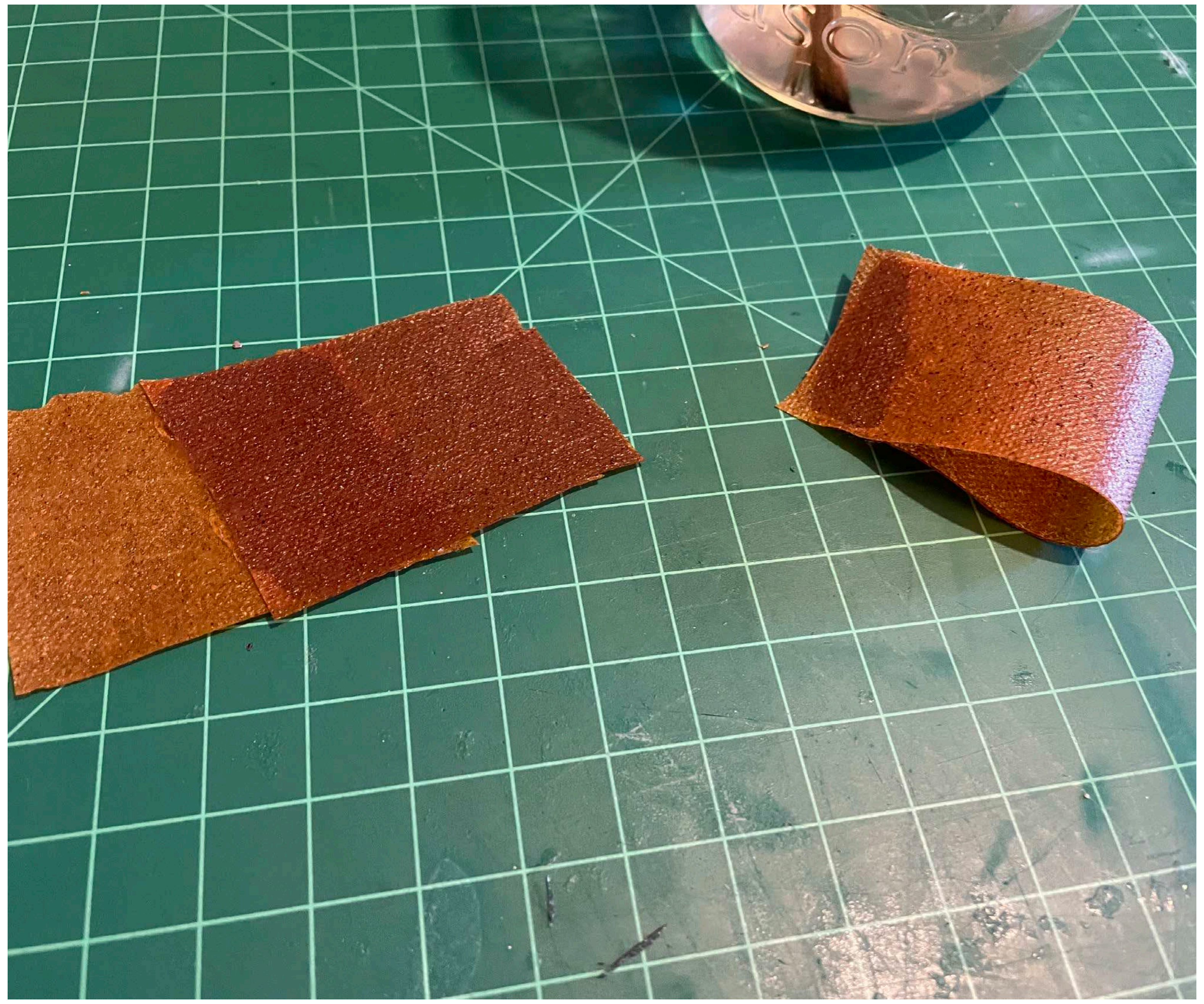
Spinach is used to attain a green dye. Blueberries are used to get blue. Beets are used to get a red hue. Turmeric is used to get orange and yellow.

The green is more brown than I would like and the blue is more purple, but they may look more appealing when diluted and added to the material.

Adhesive Testing

Carboxymethyl cellulose is used as a glue. I tested increasing its adhesive abilities by mixing with agar and heating.





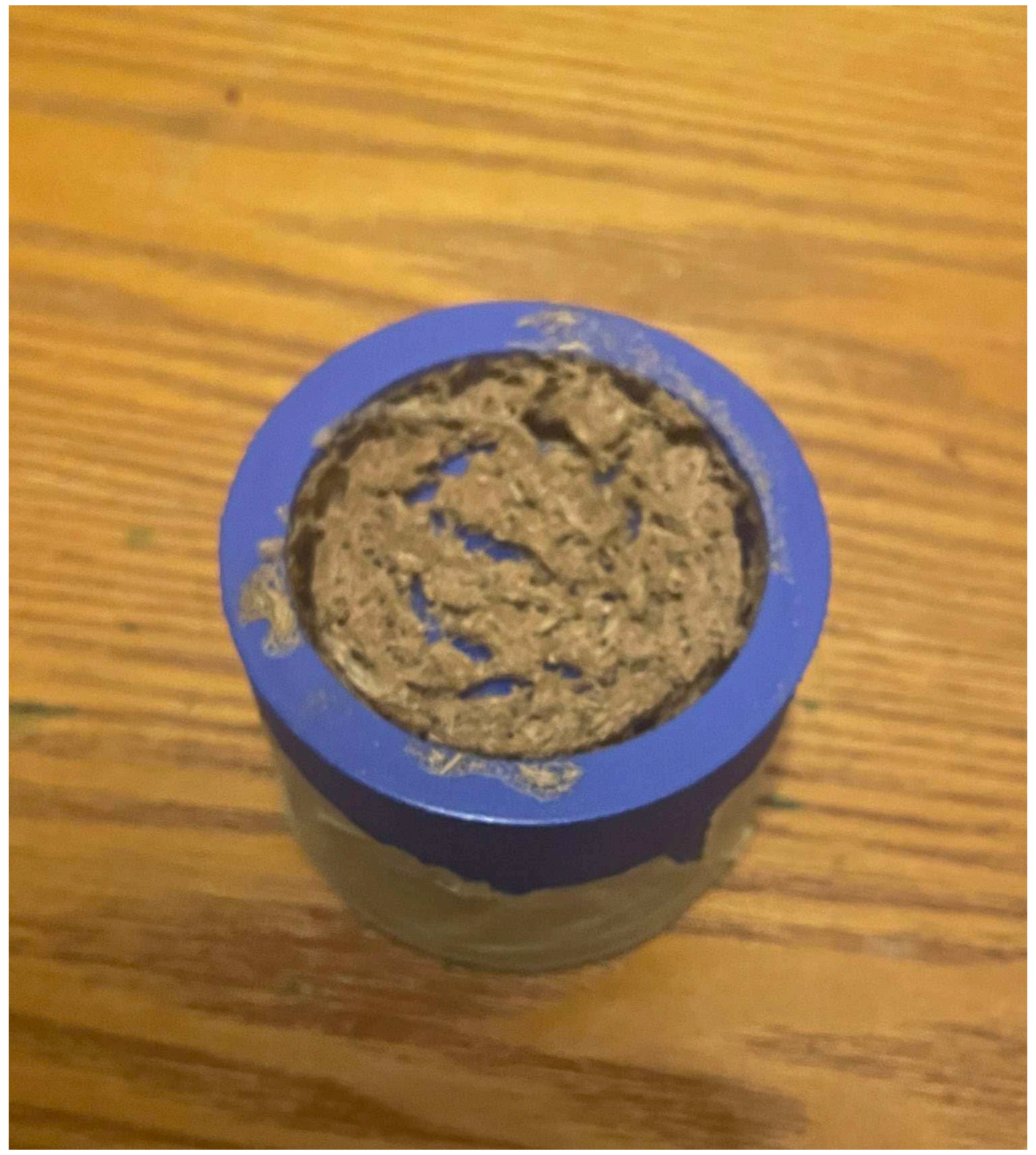
The glue held fairly strong and was stronger than CMC glue on its own. It takes around 30 minutes to dry. It does not withstand forceful pressure.

Material Prototyping

With the main materials figured out, there are some finishing touches that are needed to make the materials stronger, longer-lasting, and more aesthetically pleasing.

Bamboo Composite Molds

Although the bamboo composite is strong, rigid, and shows potential, the dramatic shrinking poses a problem for production.

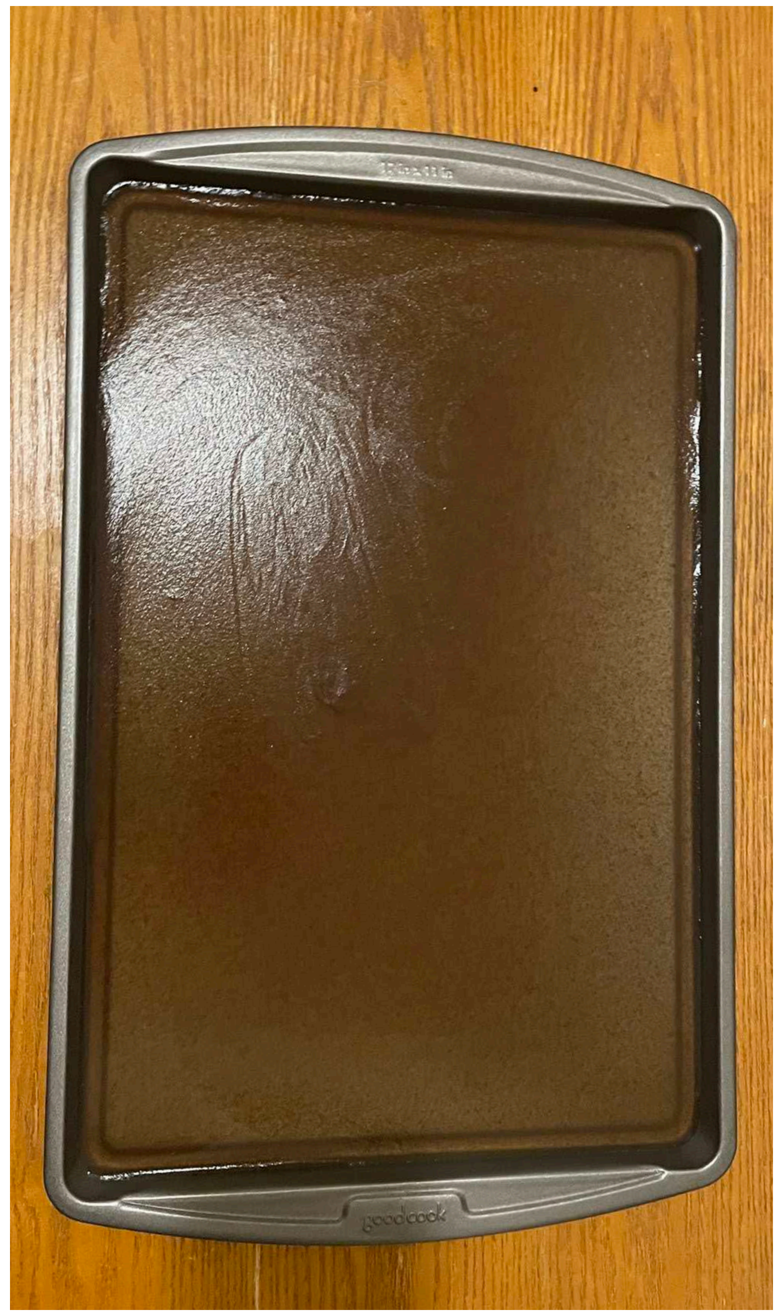


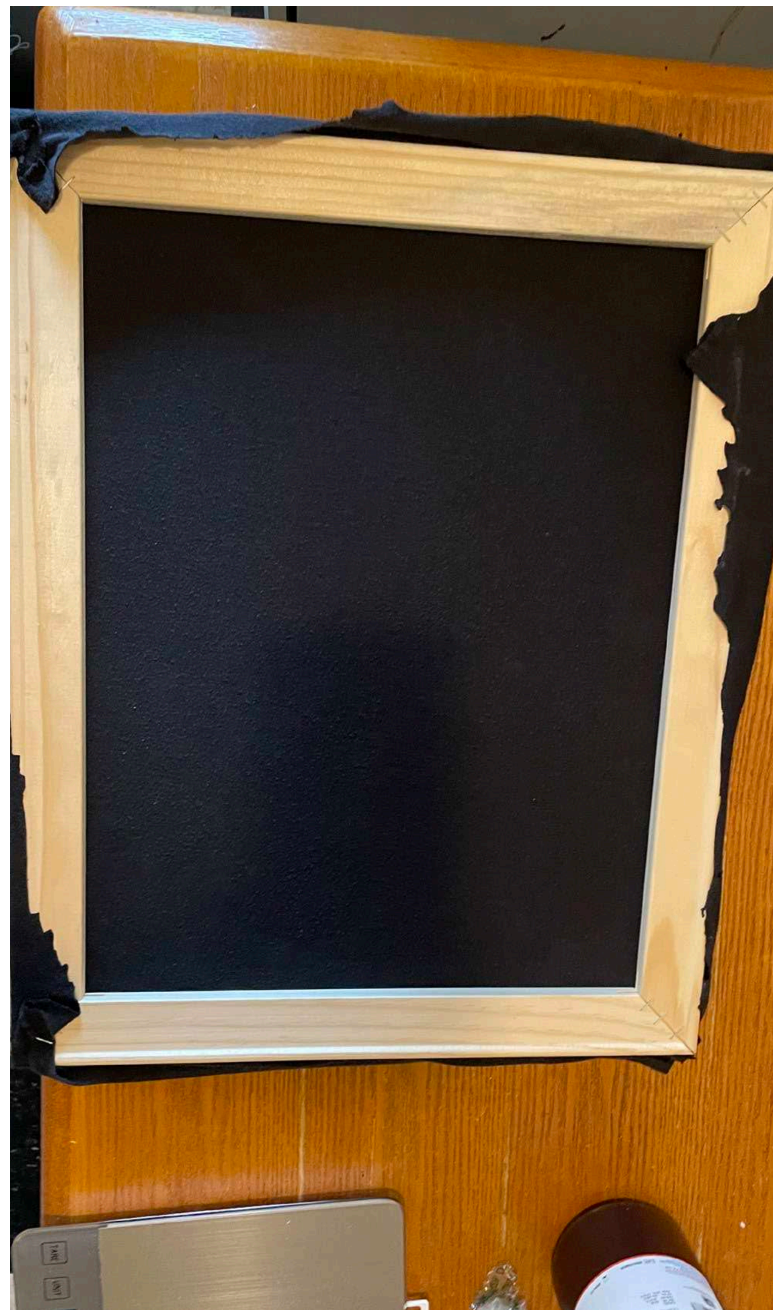
To reduce drying time and solve shrinking, I tested pouring small layers of the bamboo and agar composite in 3d-printed molds and then dehydrating them. When a layer is done drying, I add another to unite the shrunk pieces.

Unfortunately, the small layers still took over 8 hours to dry enough to add the next layer. It was not feasible to explore this further.

Scaling and Sheet Production

To create prototypes, I needed more material. To create larger sheets, I needed to solve the shrinking/curling issue and reduce the drying time.



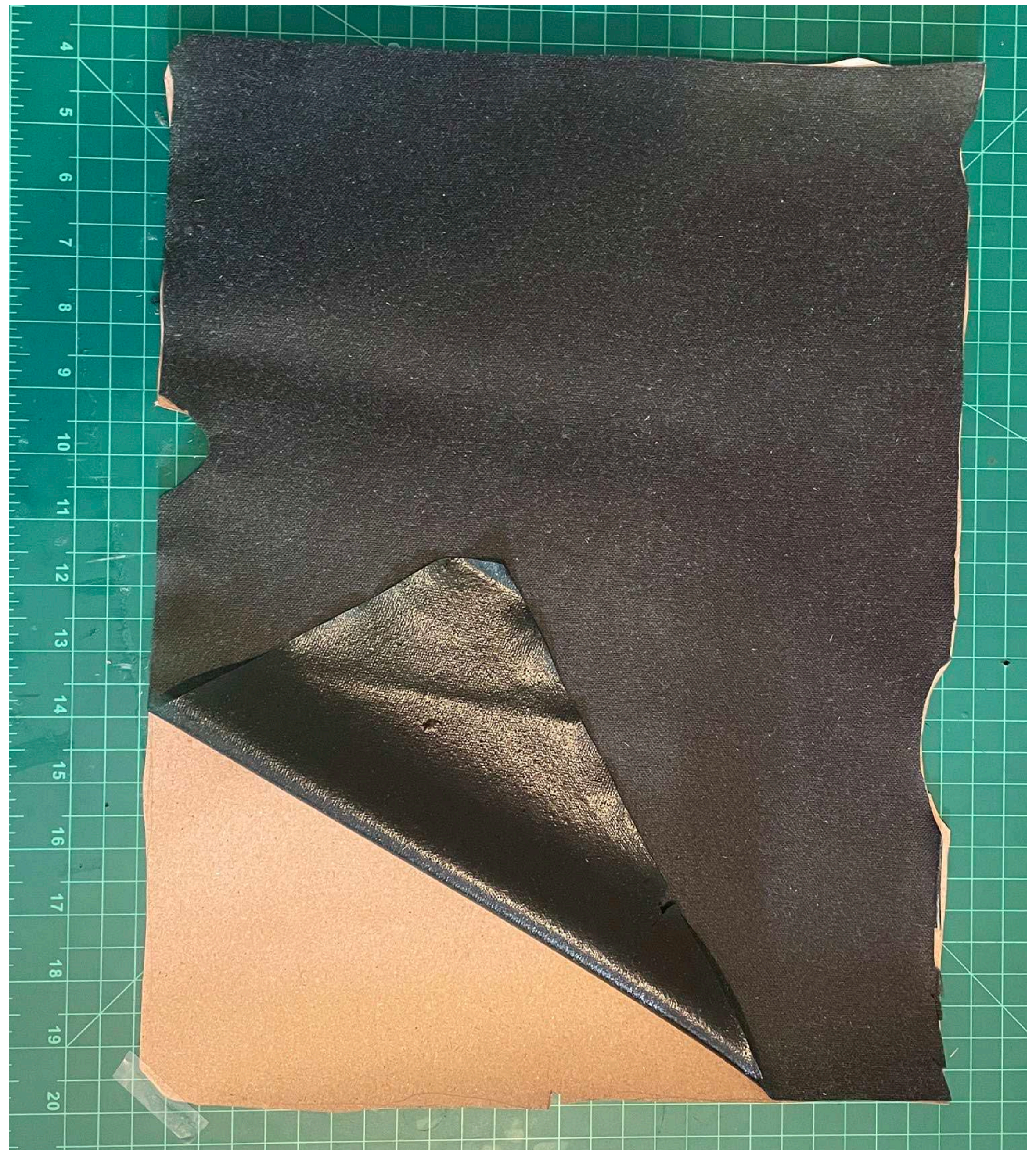


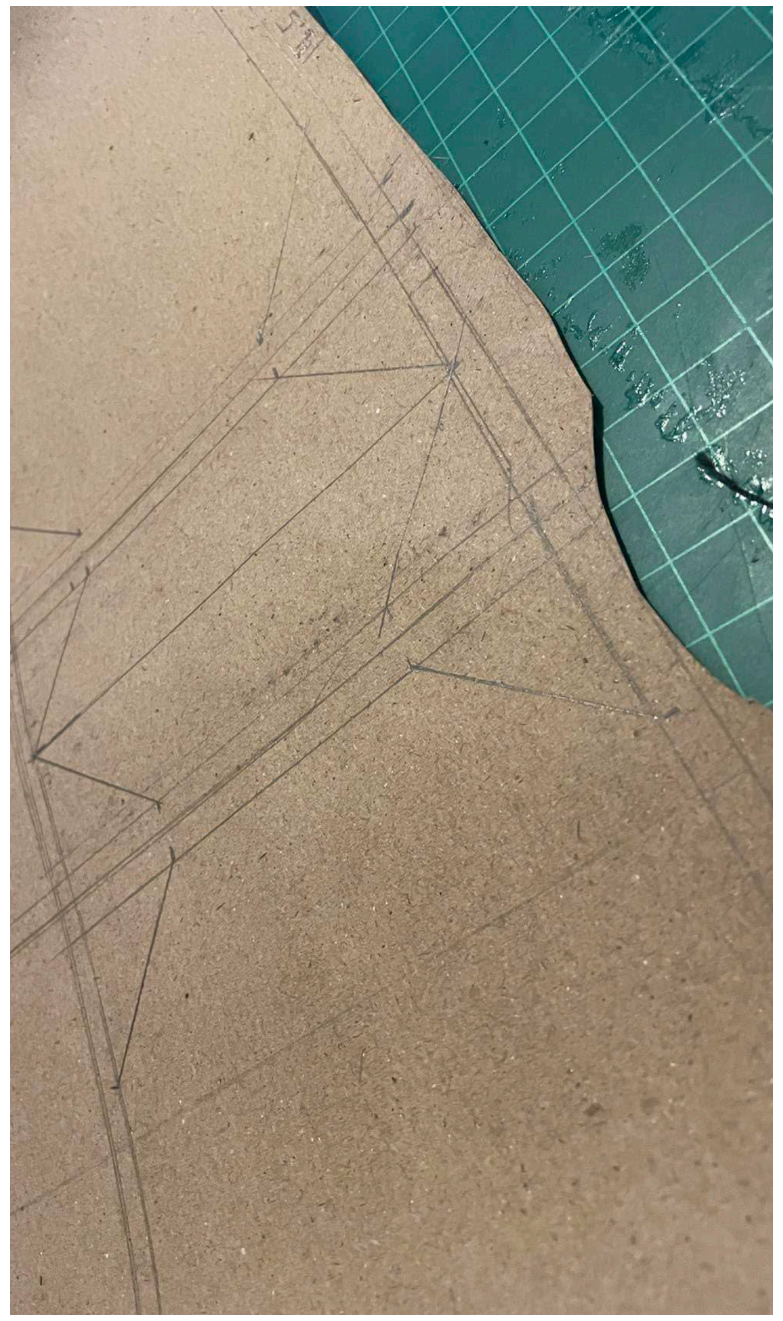
I first tested a sheet pan with another weighted sheet pan on top, dehydrating in the oven. The stacked sheet pan did not let enough water to escape but the material would curl without it.

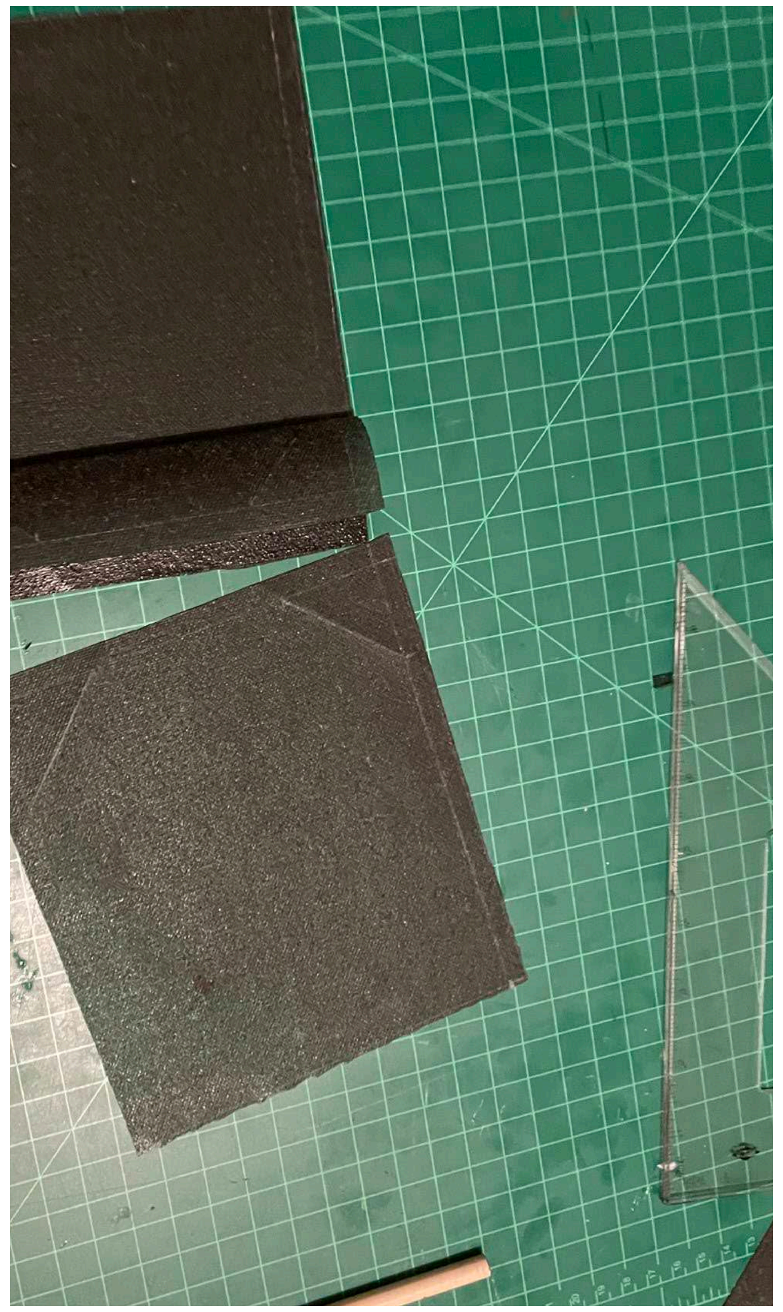
I then tried stretching fabric around a frame. This led to canvas. With added lubrication, the bioplastic sticks while drying and does not curl but can be removed when dried. The canvas allows moisture to escape on both sides and reduce dry time. When put in the oven at 170 °F, the agar bioplastic takes around 7 hours to fully dry.

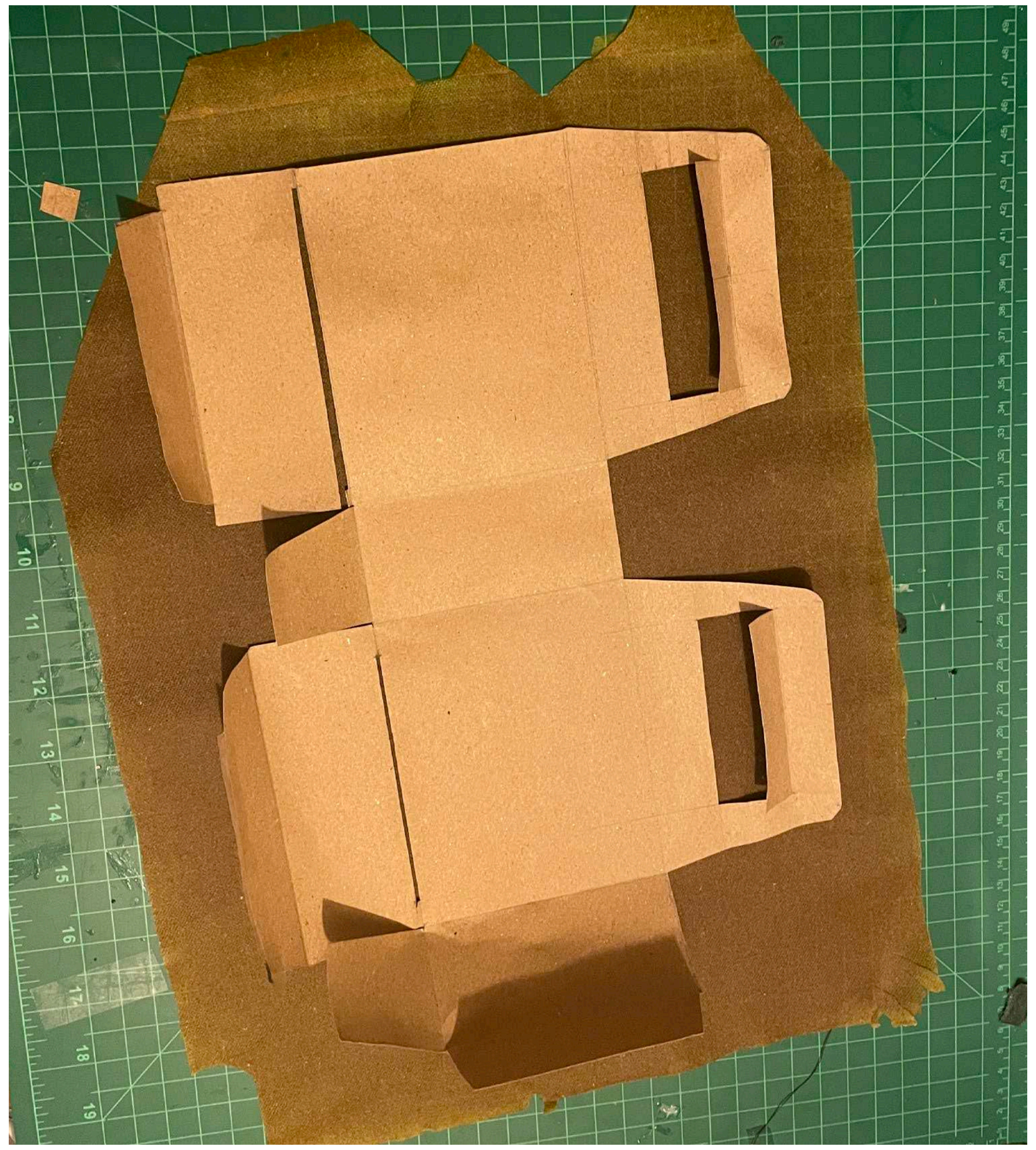
Agar Bioplastic Packaging

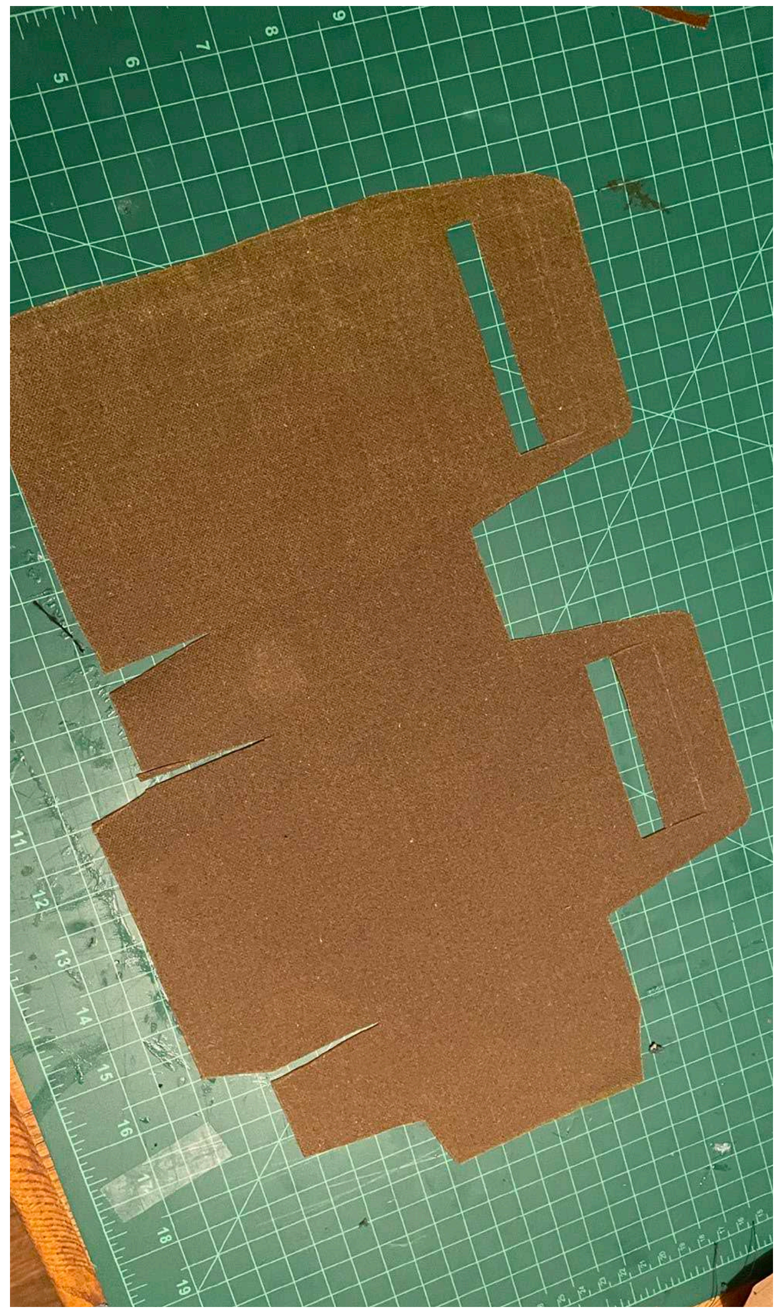
The basic bioplastic sheets have similar properties to plastic sheets. I created prototypes as a replacement for plastic bags and packaging





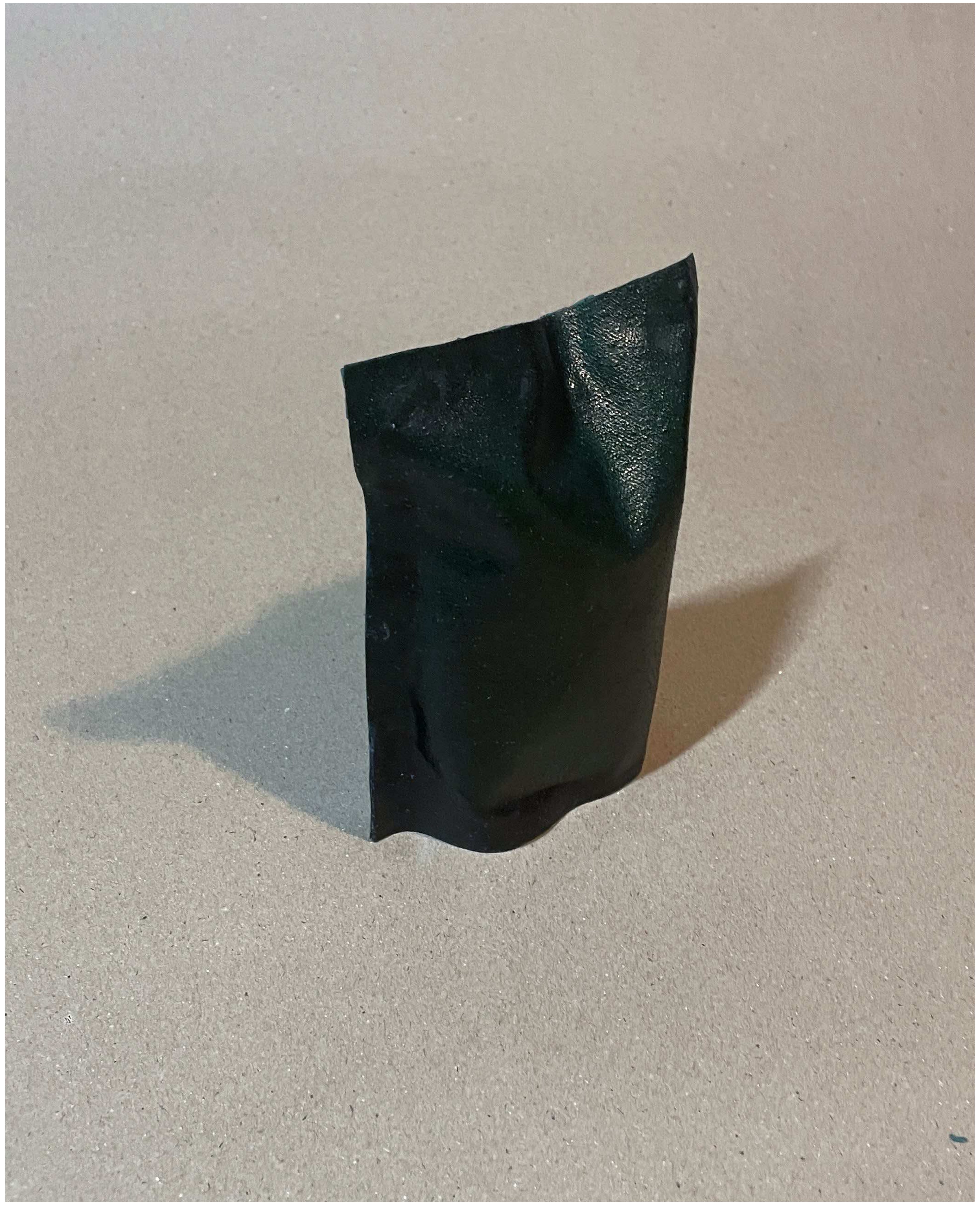


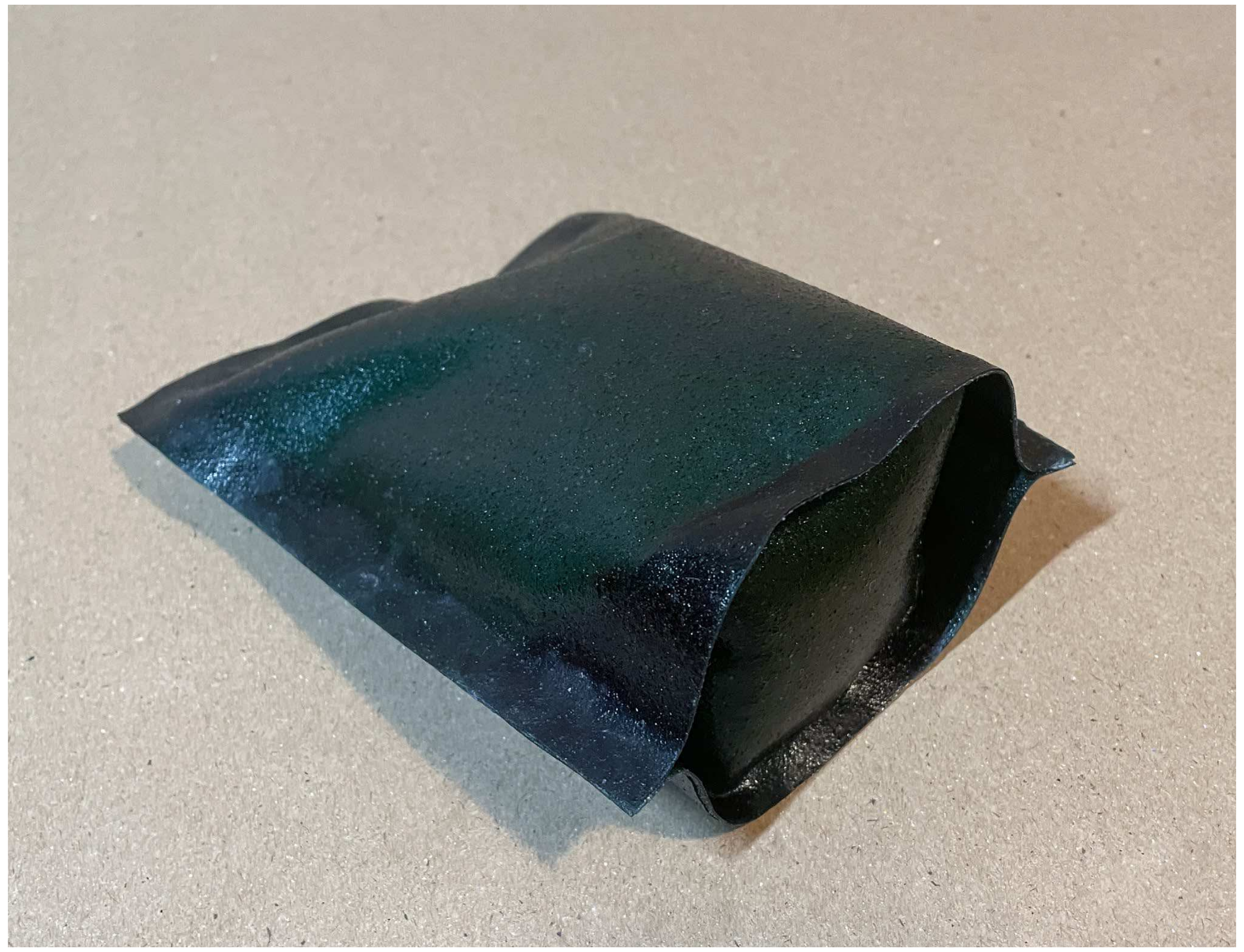




First, paper prototypes and patterns are made within the constraints of the plastic sheets. The bioplastic is then cut into the pattern and made into packaging and prototypes.

Agar Bioplastic Pouch



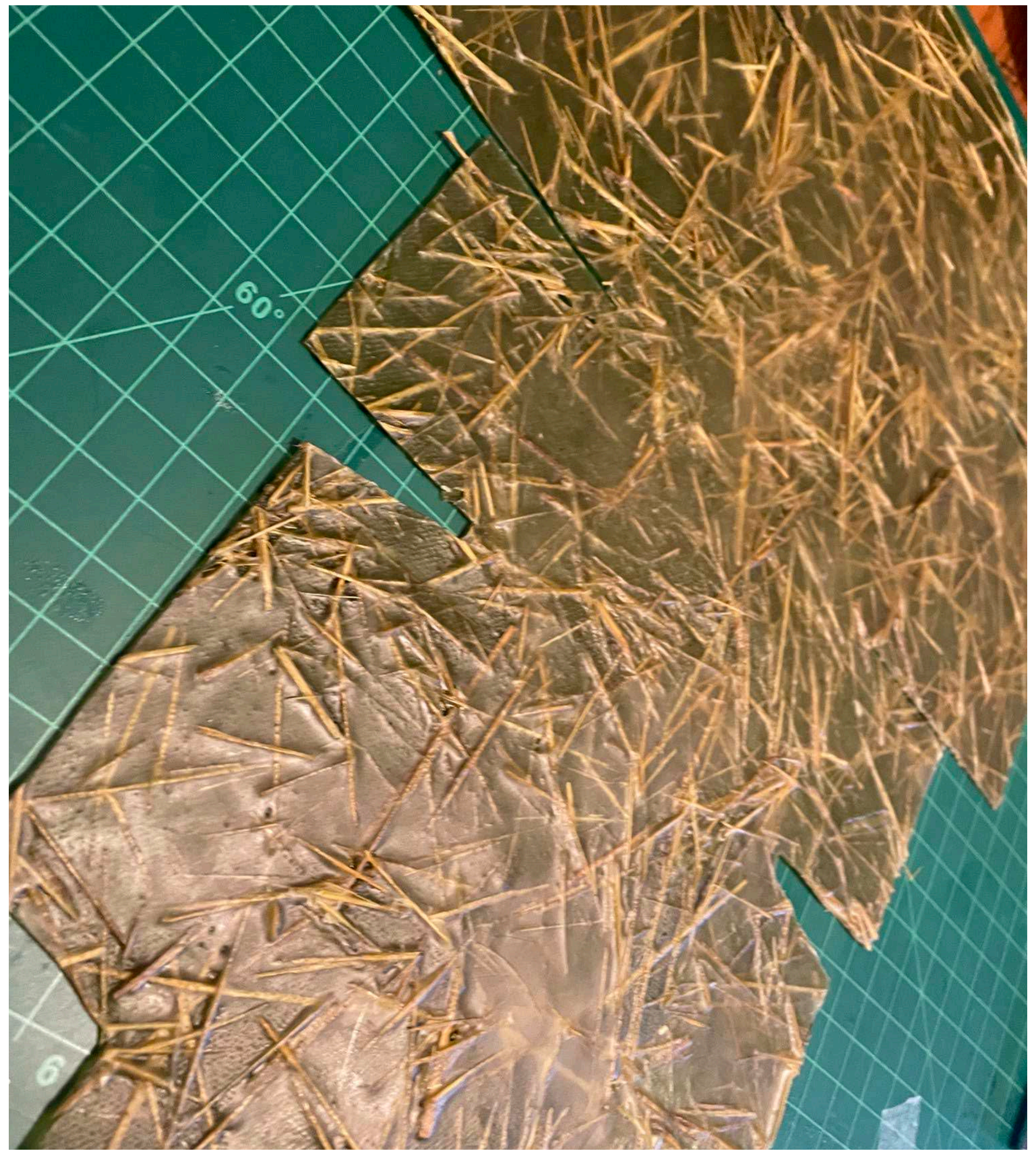


Agar Bioplastic Bag



Bamboo Fiber + Agar Packaging

The more rigid properties of the bamboo fiber and agar composite make it useful for more sturdy packaging.



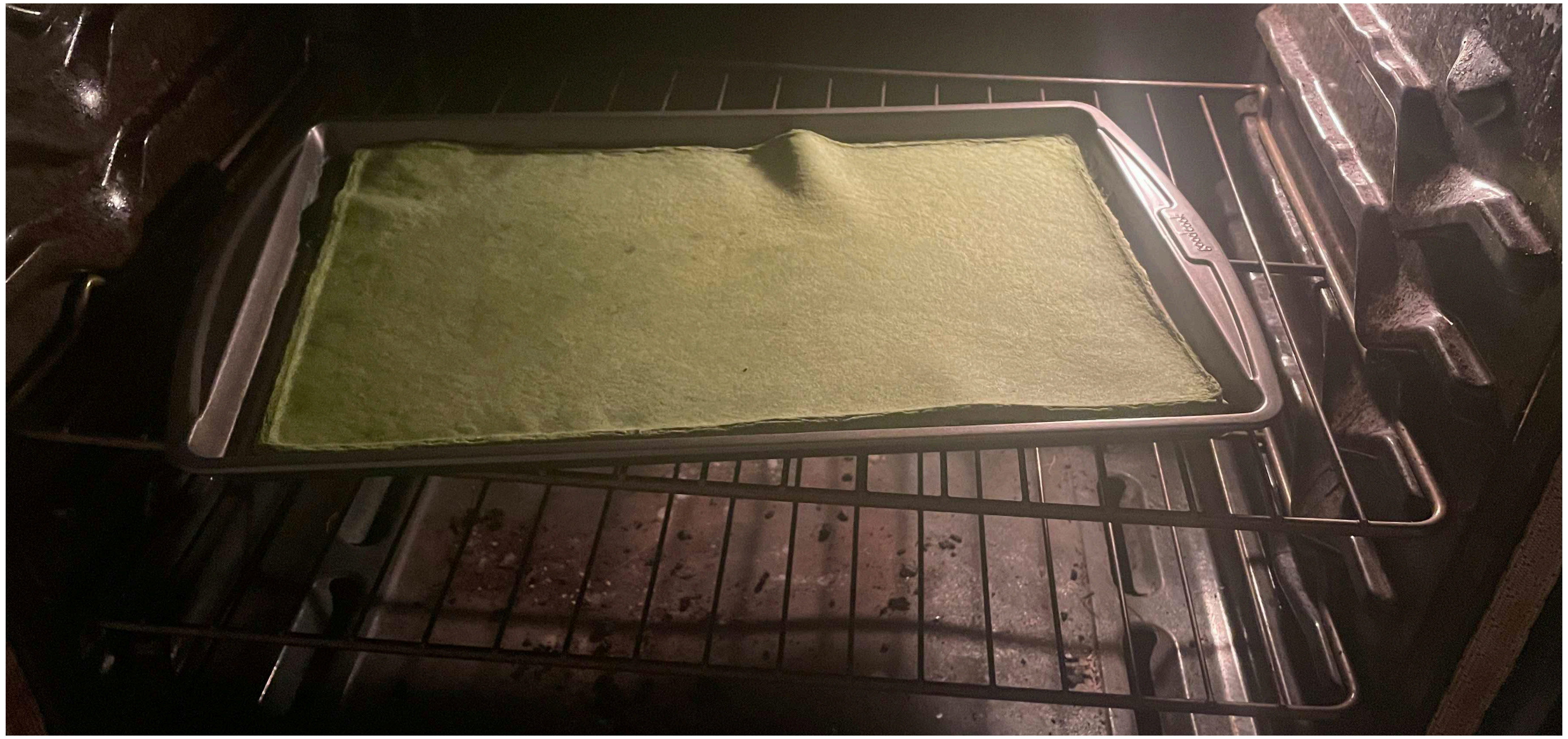
A sheet of the fiber composite is made. Beeswax is added to the inside for additional protection, waterproofing, and rigidity.

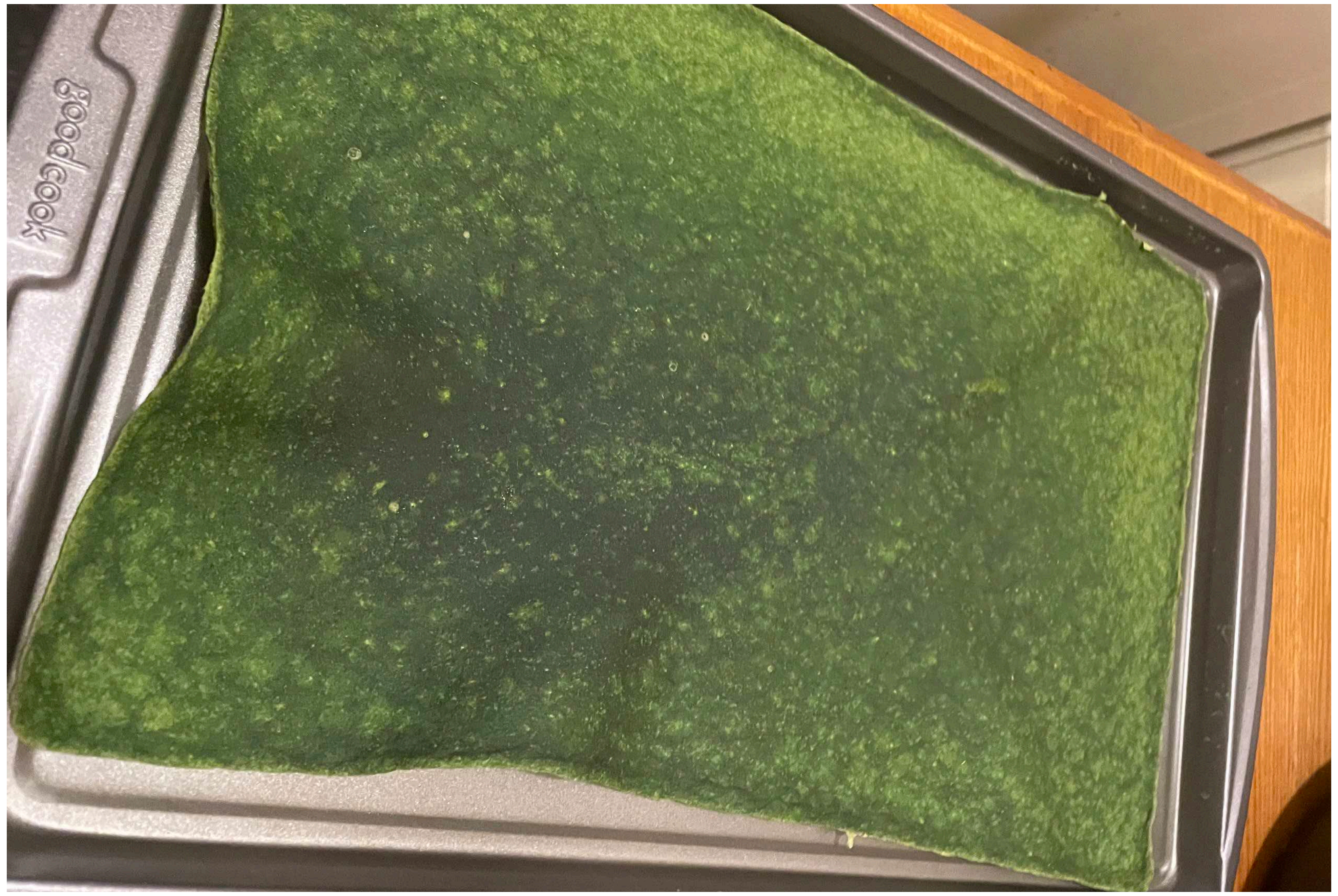
The material is made into a box that could be used as a takeout container or packaging.

Bamboo Fiber + Agar Bioplastic Box

Cellulose Leather Sheet Production

A similar drying process was used for the cellulose leather.



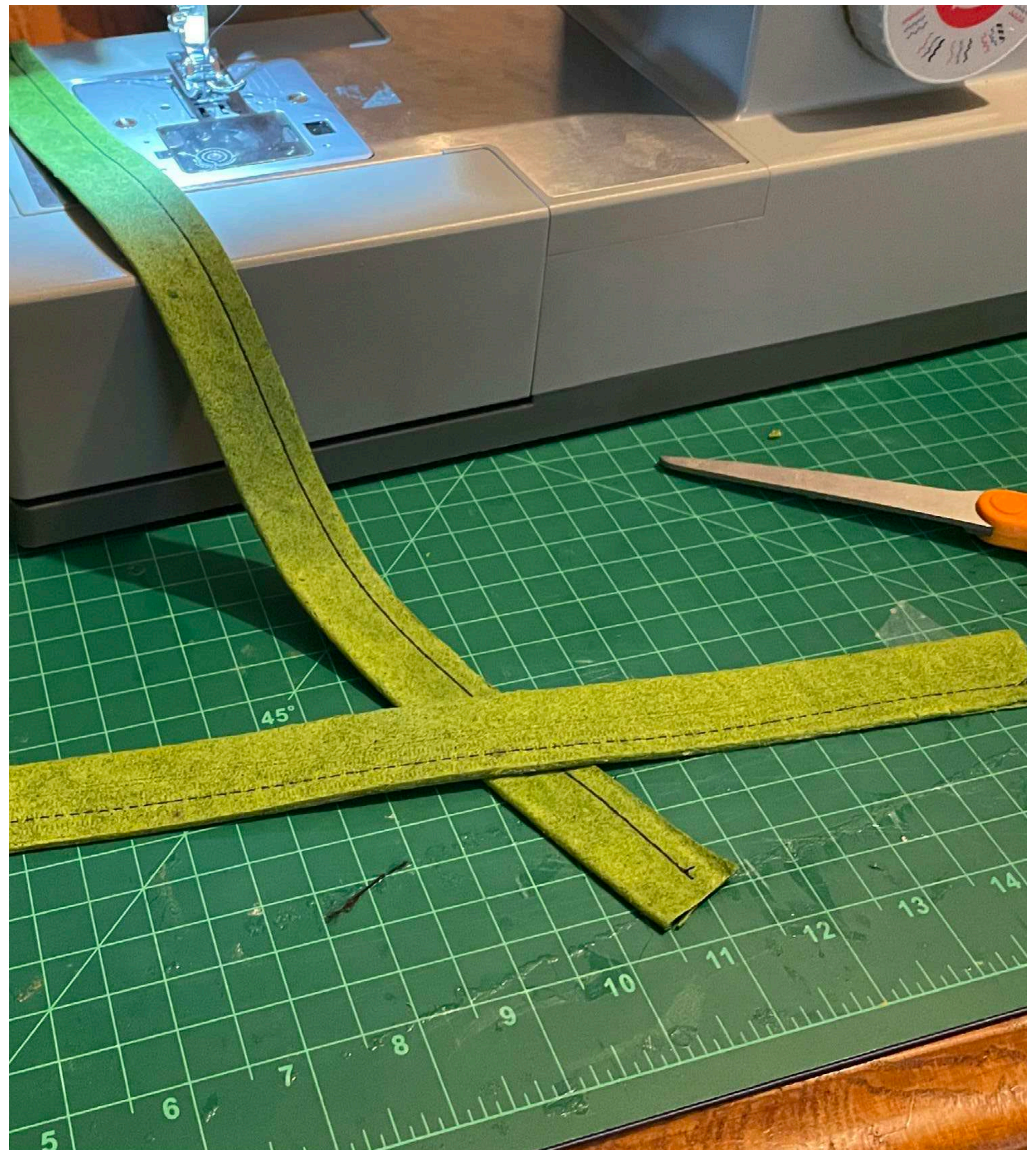
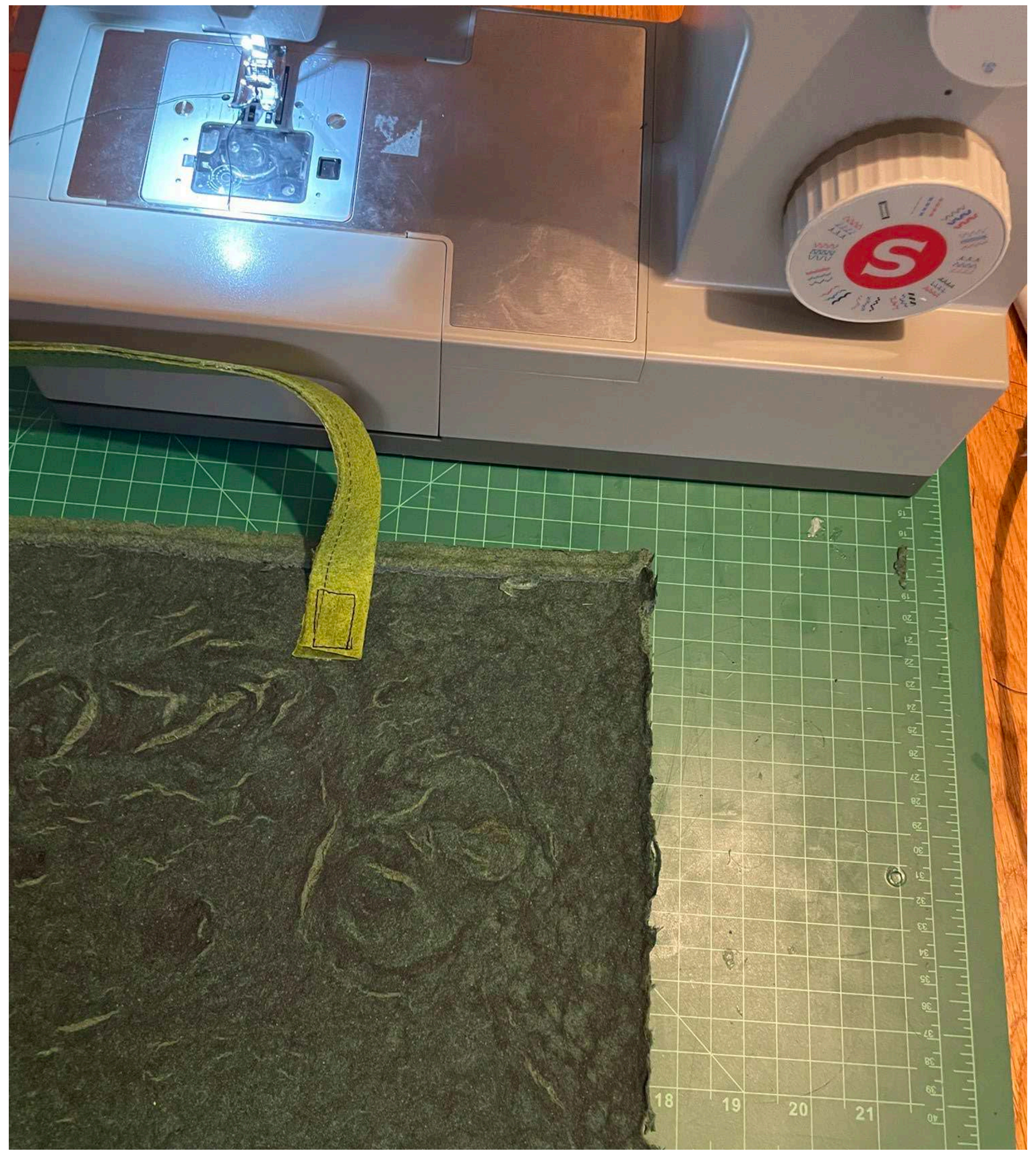
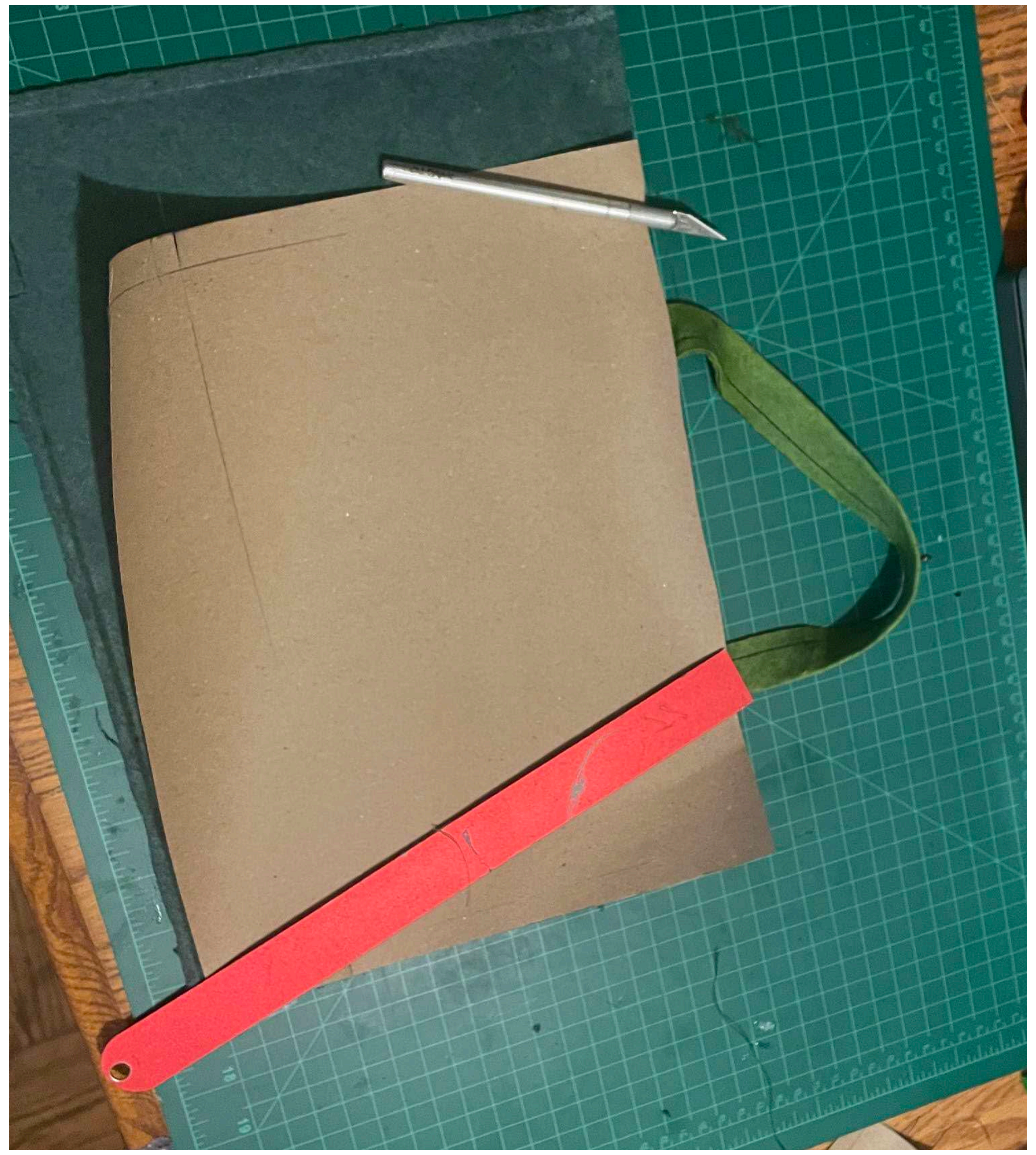


The final cellulose leather recipe replaces cornstarch with agar, but keeps the pulp as the fiber.

The cellulose leather has les of a tendency to shrink, so a sheet pan could be used. The material takes around 5 hours to fully dry in a 170 °F oven.

Cellulose Leather bag

Cellulose leather's fabric-like qualities make it useful as a small bag or tote.

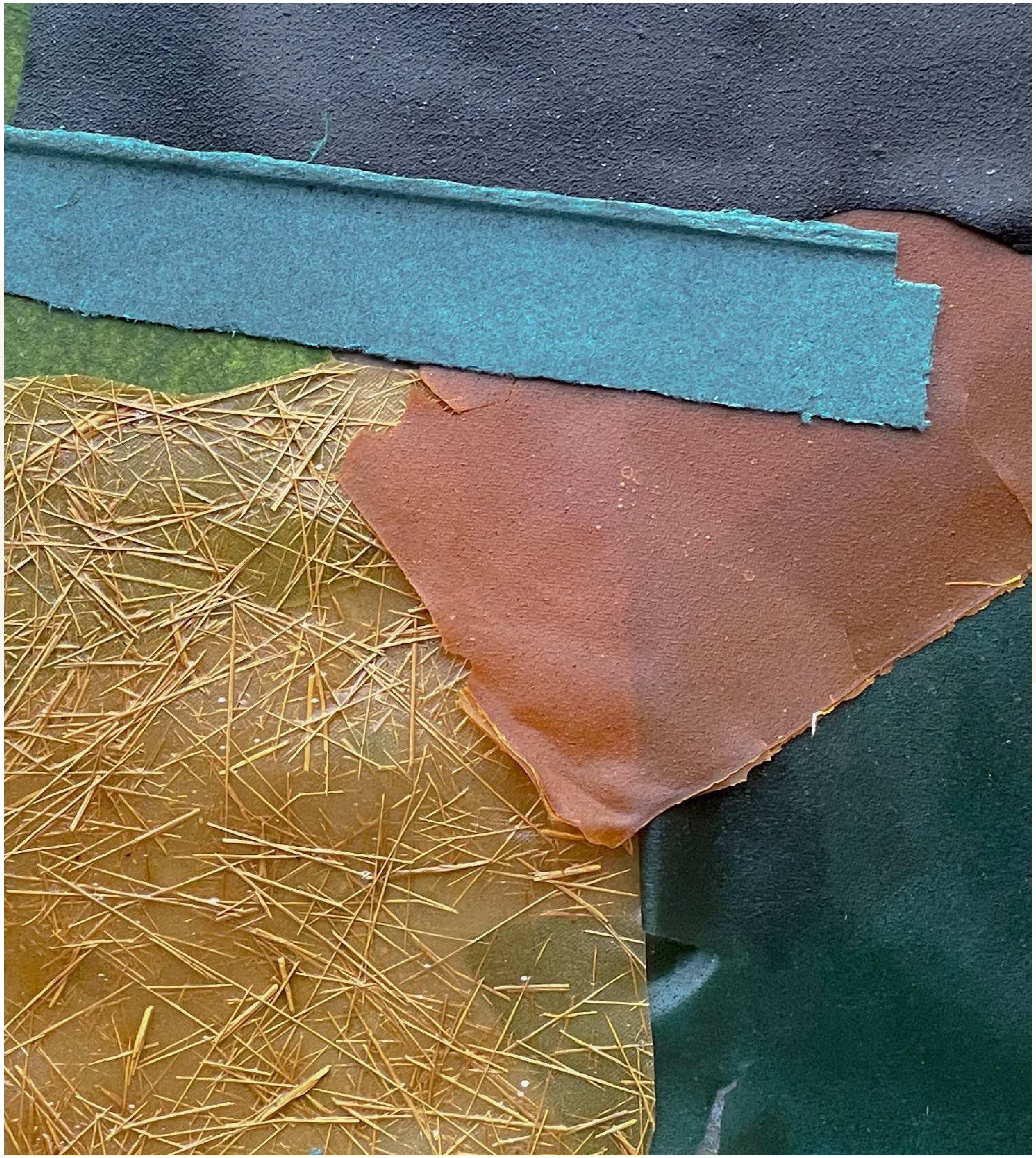





I tested sewing the cellulose leather and other methods of construction. Unfortunately, the more I worked with the material the weaker it became. It is fragile and prone to tearing. An increase in agar concentration could potentially strengthen the material and solve this issue.

Cellulose Leather bag

Material Advantages

These materials are entirely plant based, and practically edible. The materials used are not energy-intensive to produce. They are entirely biodegradable.



Lifecycle: Semi-disposable

Lifecycle

The bioplastic is waterproof as long as the temperature isn't too high. With continued testing, these biomaterials could be nearly as strong as their plastic counterparts.

Disposal

This product is made completely out of bio-degradable materials. The user can easily compost the product.

If it is thrown out it will biodegrade within a few weeks within the elements. The materials release very minimal carbon and aren't harmful to animal or plantlife.

Thank you.