Carbon Footprint

Are bioplastics harmless for the environment?

Agar and corn starch based bioplastics are derived from plants that consume carbon dioxide and release oxygen during their life. But once they are harvested, they are processed and transported around the world. This requires fuel which is most likely sourced from petroleum, a finite resource, and causes carbon dioxide to be emitted into the atmosphere. It is best to make bioplastics from ingredients that are sourced locally to reduce the petroleum used for transport. Furthermore, it is better to have a relationship with the supplier of the materials to understand how they are being processed. Are these plants GMOs? Are they cultivated with fertilizers and pesticides? The idea of plant based plastics seems nice, but the agriculture industry can be extremely damaging to the environment.

The gelatine in gelatine based bioplastics comes from pig collagen. Pig production has a large carbon footprint, as pigs produce greenhouse gases, such as methane and nitrous oxide. They consume processed feed, breathe oxygen, and exhale carbon dioxide. Farming animals takes up land and reduces biodiversity. However, pigs are mainly farmed for pork consumption, so extracting gelatine from pig collagen makes use of waste from the food industry. By using gelatine the negative environmental impact of a pig carcass is decreased, as more of its body will go to use.

It is recommended that bioplastics created using these recipes are melted and recast, so that they can be reused endlessly, but if not, make sure that they are disposed of properly. Even though these are plastics, they should not be recycled with petroleum based plastics, or else they will contaminate the recycling stream. If they are disposed of with landfill waste they may take a very long time to biodegrade as they will have limited exposure to oxygen. It is best to compost bioplastics in a hot and aerobic environment.

Create your own catalogue of bioplastics by printing out this label with the dimensions 105mm x 88mm:

Bioplastic -

Bioplastic

Biopolymer	Plasticizer	Additive	Solvant	Property

Notes:

Material Designer:

FABTEXTILES
Iaac | FAB LAB BARCELONA

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I would like to thank Anastasia Pistofidou, my internship mentor, for her guidance and for the commission of this book

&

Clara Davis and Rose Ekwé for their advice on bioplastics.

Bioplastic Cook Book

for FABTEXTILES
by Margaret Dunne

A catalogue of bioplastic recipes.

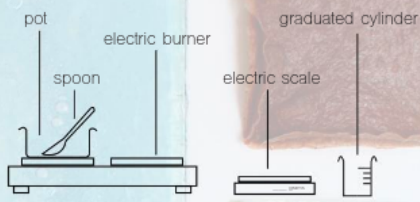
What is a Bioplastic?

A bioplastic is a biobased polymer derived from a biomass, and it may or may not be biodegradable. The following bioplastic recipes mentioned in this book are all biodegradable. Bioplastics are generally comprised of a biopolymer, a plasticizer and a solvent. Non biodegradable bioplastics include biobased PET and PE.

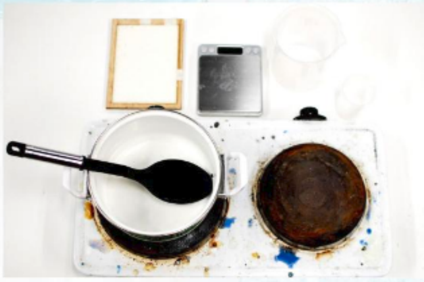
Bioplastic Basics:

-Bioplastics behave like glue and will stick to wood. For casting it is best to pour onto a non porous surface like glass or plastic, especially acrylic.
- To make flat sheets of bioplastic, cast the bioplastic mix in a wooden frame, let them dry and then cut them out from the frame.
-Bioplastics can be reused. If they are broken into small pieces and heated with water until they dissolve, they can be recasted into a new form.
-As bioplastics are thermoplastics with low melting points, they can be deformed by long periods of sun exposure.
-Bioplastics are not water resistant. They will deform if they are exposed to rain, or get wet. This also means that they are biodegradable!
-To improve water resistance, add wax to the bioplastic solution.
-Fibers, minerals, or food waste can be added to bioplastic recipes to create a biocomposite.
-Expect bioplastics to shrink as water evaporates during the drying process. Bioplastics with a low percentage of glycerine are likely to shrink more.
-If bioplastics are colder than the ambient temperature, when touched, they are still drying.
-Casting thick bioplastics may result to mold. Cover them with a textile to keep the bioplastic clean.

Apparatus Setup:



This equipment can be used to make any and all of the bioplastic recipes in this book. The recipes were made to be cast into a wooden laser-cut frame, with inner dimensions of 105 mm x 148 mm.



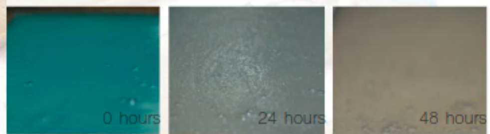
Observations

Agar Agar Shrinking

The agar bioplastic solution is comprised mostly of water, so when it dries it will shrink as its components are lost to evaporation. In addition to shrinkage, the evaporating water puts a lot of stress on the bioplastic that may lead to cracking. In bioplastics with a low concentration of glycerine, cracking is more likely to occur. It is best to cook the agar solution for longer to boil off more water before leaving the mixture to air dry.

Agar + Spirulina Colour Loss

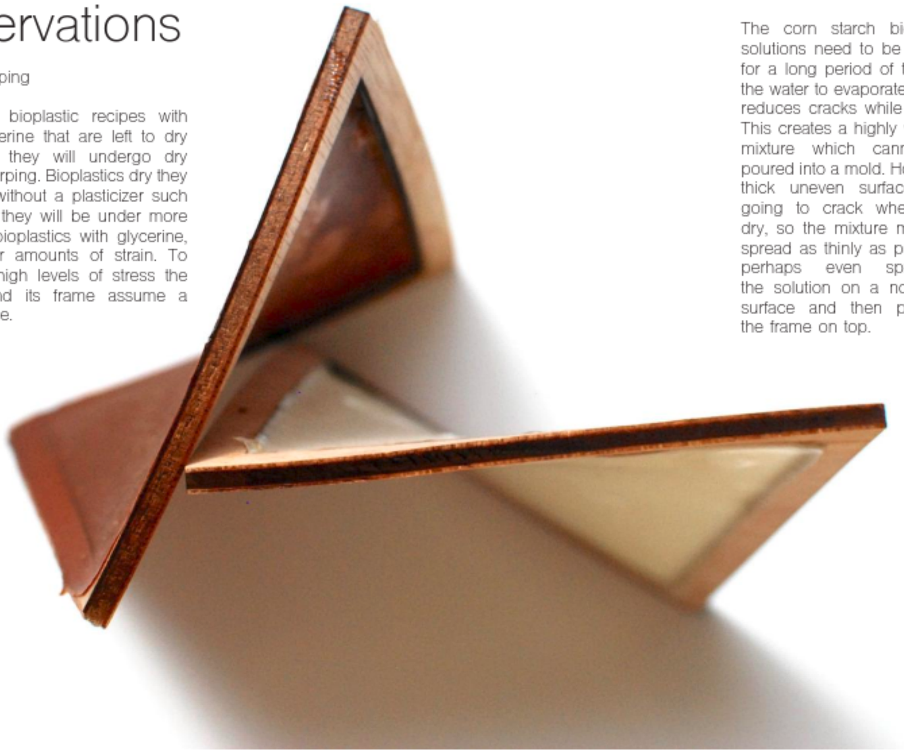
As more heat is required to dissolve agar than gelatine, spirulina was not a successful source of pigment for agar agar bioplastic. The phycocyanin protein denatured within 15 seconds of being added to the hot solution. When all of the phycocyanin sugar water solution was added after the bioplastic solution was removed from heat, the blue colour faded over time while the bioplastic dried. The photos on the left show the colour change over a period of 3 days.



Observations

Gelatine Warping

For gelatine bioplastic recipes with 0.0g of glycerine that are left to dry in a frame, they will undergo dry shrinkage warping. Bioplastics dry they shrink, and without a plasticizer such as glycerine they will be under more stress than bioplastics with glycerine, facing similar amounts of strain. To reduce the high levels of stress the bioplastic and its frame assume a warped shape.



Corn Starch Cracking

The corn starch bioplastic solutions need to be heated for a long period of time for the water to evaporate, which reduces cracks while drying. This creates a highly viscous mixture which cannot be poured into a mold. However, thick uneven surfaces are going to crack when they dry, so the mixture must be spread as thinly as possible, perhaps even spreading the solution on a non-stick surface and then pressing the frame on top.

Gelatine

Animal Based Bioplastic

Ingredients

Recipe	Brittle	>		Flexible
Glycerine (g)	0.0	1.8	3.6	7.2
Water (ml)	60	60	60	60
Gelatine (g)	12	12	12	12

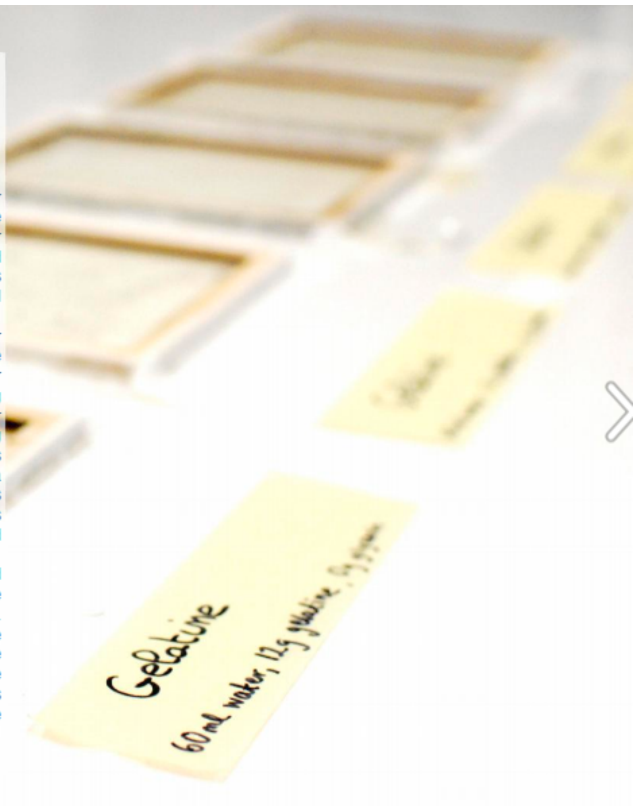
Recipe

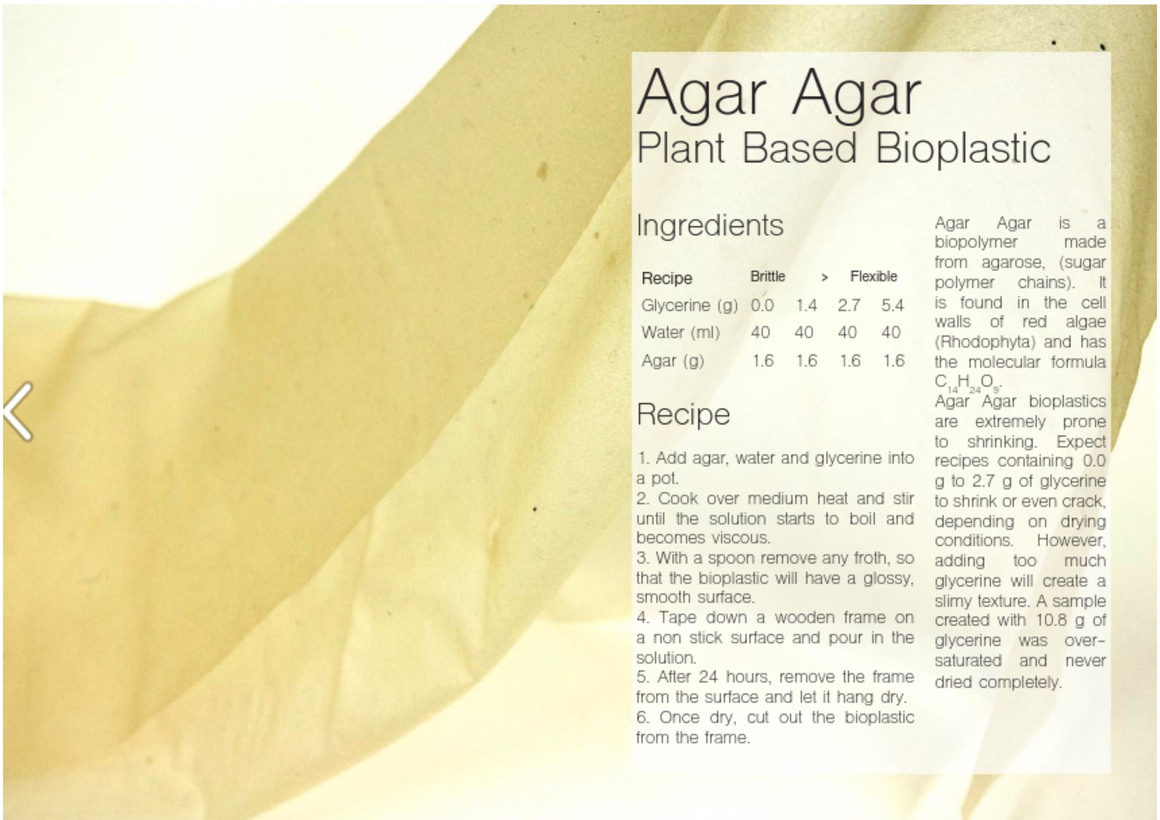
1. Add gelatine, water and glycerine into a pot.
2. Cook over medium heat and stir until the gelatine is dissolved and the solution starts to thicken.
3. With a spoon remove the froth, so that the bioplastic will have a glossy, smooth surface.
4. Tape down a wooden frame on a non stick surface and pour in the solution.
5. After 24 hours, remove the frame from the surface and let it hang dry.
6. Once dry, cut out the bioplastic from the frame.

Gelatine is a biopolymer found in pig skin, made from protein polymer chains of amino acid monomers. It dissolves in water, forming a gel substance.

Glycerine, a plasticizer creates space between the polymer chains, weakening the intermolecular forces and reducing rigidity. Glycerine has the molecular formula $C_3H_8O_3$ and it occurs naturally in fats/lipids of both animals and plants.

Gelatine is combined with glycerine to make more flexible plastics. Bioplastics with more glycerine are more flexible materials, while bioplastics with less glycerine are more brittle.





Agar Agar
Plant Based Bioplastic

Ingredients

Recipe	Brittle	>		Flexible
Glycerine (g)	0.0	1.4	2.7	5.4
Water (ml)	40	40	40	40
Agar (g)	1.6	1.6	1.6	1.6

Recipe

1. Add agar, water and glycerine into a pot.
2. Cook over medium heat and stir until the solution starts to boil and becomes viscous.
3. With a spoon remove any froth, so that the bioplastic will have a glossy, smooth surface.
4. Tape down a wooden frame on a non stick surface and pour in the solution.
5. After 24 hours, remove the frame from the surface and let it hang dry.
6. Once dry, cut out the bioplastic from the frame.

Agar Agar is a biopolymer made from agarose, (sugar polymer chains). It is found in the cell walls of red algae (Rhodophyta) and has the molecular formula $C_{14}H_{24}O_9$.

Agar Agar bioplastics are extremely prone to shrinking. Expect recipes containing 0.0 g to 2.7 g of glycerine to shrink or even crack, depending on drying conditions. However, adding too much glycerine will create a slimy texture. A sample created with 10.8 g of glycerine was over-saturated and never dried completely.

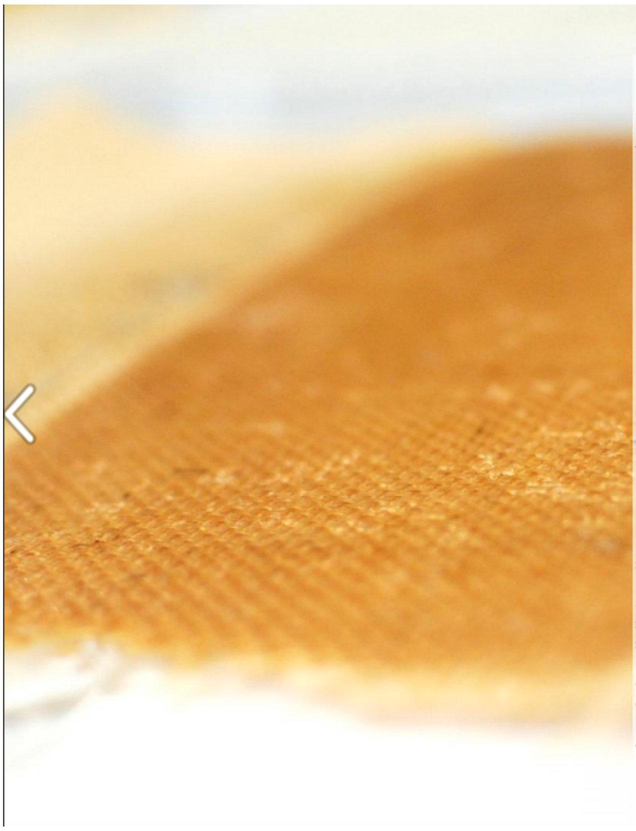
Agar Agar + Hemp
Plant Based Bioplastic Fiber Composite

Ingredients

Recipe	
Glycerine (g)	2.7
Water (ml)	40
Agar (g)	1.6
Hemp	

Recipe

1. Add agar, water and glycerine into a pot.
2. Cook over medium heat and stir until the solution starts to boil and becomes viscous.
3. Pull apart the hemp roving so that the fibers are separated into a non-oriented mass. Submerge the hemp into the bioplastic solution.
4. Remove the hemp and squeeze out as much excess bioplastic solution as possible. Place the saturated hemp on a non-stick surface and then place a sheet of non-stick material on top of the hemp and cover with a weight to compress the composite.
5. After 24 hours, remove the weight and the non-stick surfaces.
6. Let the biocomposite hang dry.



Gelatine + Burlap

Animal Based Bioplastic Textile Composite

Ingredients

Recipe	
Glycerine (g)	3.6
Water (ml)	60
Gelatine (g)	12
Burlap (mm)	105x148

Recipe

1. Add gelatine, water and glycerine into a pot.
2. Cook over medium heat and stir until the gelatine is dissolved and the solution starts to thicken.
3. With a spoon remove the froth.
4. Place the burlap on a non-stick surface, and pour on the bioplastic solution. Place a sheet of non-stick material on top of the burlap and cover with a weight to compress the composite.
5. After 24 hours, remove the weight and the non-stick surfaces.
6. Let the biocomposite hang dry.

Burlap is a plain weave fabric made from yarns spun from coarse jute fibers. Jute is a bast fiber from the plant *Corchorus capsularis.* Jute is comprised of cellulose and lignin and is known for its high tensile strength and low extensibility.

As a plain weave, burlap has poor drape and by combining burlap with bioplastic to create a composite, the drape of this new textile decreases even more. Burlap+bioplastic composite materials have high stability and low extensibility in both the warp and weft direction. These composite materials are characterized by having a high strength to weight ratio.

Corn Starch

Plant Based Bioplastic

Ingredients

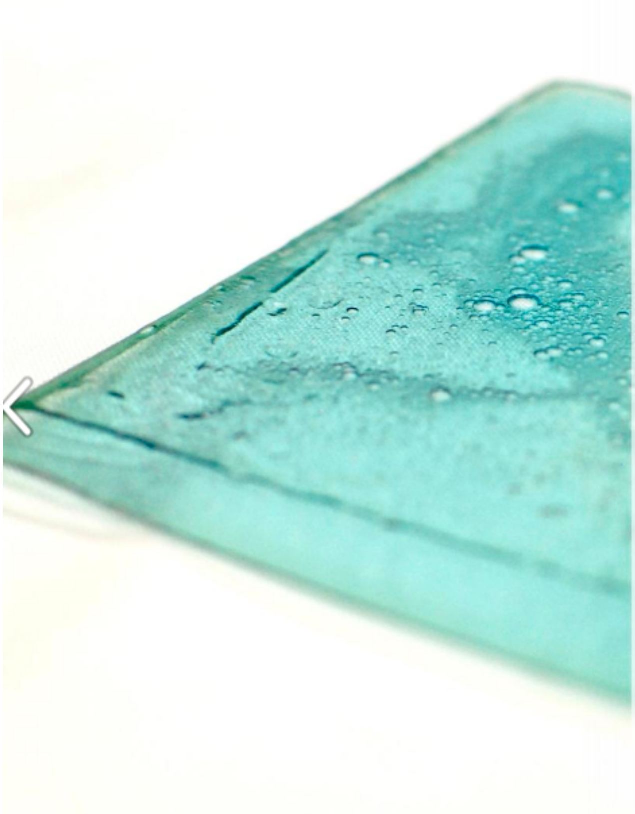
Recipe	Brittle	>		Flexible
Glycerine (g)	0	5	10	20
Water (ml)	80	80	80	80
Corn Starch (g)	1.6	1.6	1.6	1.6
Vinegar (ml)	15	15	15	15

Recipe

1. Add corn starch, water, glycerine and vinegar into a pot.
2. Cook over medium heat and stir for 10 minutes. Continue to heat after the solution becomes viscous to evaporate the excess liquid.
3. Tape down a wooden frame onto a non stick surface. Spoon a thin layer of the mixture into the frame (if it is too thick it will crack as it dries).
4. After 24 hours, remove the frame from the surface and let it hang dry.
5. Once dry, cut out the bioplastic from the frame.

Corn Starch, $C_{27}H_{48}O_{20}$ is composed of amylose and amylopectin polymers. Both of these polymers consist of glucose (sugar) monomers. Starch granules will not dissolve on their own in water, but when heated the intermolecular bonds will break, opening up sites for hydrogen bonding. This allows the starch to dissolve in water, creating a viscous fluid.

Vinegar, a weak acid, helps to break down the amylopectin, which allows the dried bioplastic to be more flexible.



Gelatine+Spirulina

Animal Based Bioplastic with Natural Pigment

Ingredients

Recipe	Brittle	>		Flexible
Glycerine (g)	0.0	1.8	3.6	7.2
Water (ml)	50	50	50	50
Gelatine (g)	12	12	12	12
Spirulina (ml)	10	10	10	10
Sugar (g)	4	4	4	4

Recipe

1. Dissolve sugar in 50ml of water on the burner. Once dissolved, remove from heat to cool.
2. Filter water through spirulina powder, until 10 ml of blue spirulina water has been collected. Then combine this with the cooled sugar solution.
4. Add glycerine, gelatine, and 30ml of the sugar/spirulina solution in a pot and cook on a medium heat. After 2 minutes add the remaining 30ml of solution and stir. Quickly pour into a frame on a smooth non stick surface.
5. Let the bioplastic dry according to the previously stated steps.

Spirulina is a type of cyanobacteria (algae). In its dried form it is a green powder. The colour comes from green chlorophyll, which is insoluble in water, and blue phycocyanin, which is soluble in water and therefore can be isolated by filtration. The phycocyanin protein denatures when heated but adding sugar helps to stabilize the colour. Even so, bioplastic mixtures will fade from blue to green to yellow within one minute. The best colour will be achieved if the blue solution is added within 15 seconds of casting the bioplastic.

Agar Agar + Burlap

Plant Based Bioplastic Textile Composite

Ingredients

Recipe	
Glycerine (g)	2.7
Water (ml)	40
Agar (g)	1.6
Burlap (mm)	105x148

Recipe

1. Add agar, water and glycerine into a pot.
2. Cook over medium heat and stir until the solution starts to boil and becomes viscous.
3. With a spoon remove the froth.
4. Place the burlap on a non-stick surface, and pour on the bioplastic solution. Place a sheet of non-stick material on top of the burlap and cover with a weight to compress the composite.
5. After 24 hours, remove the weight and the non-stick surfaces.
6. Let the biocomposite hang dry.

The agar + burlap bioplastic composite is more flexible and has better drape than the gelatine + agar bioplastic.

Agar Agar Foam

Plant Based Bioplastic with Soap

Ingredients

Recipe	
Glycerine (g)	2.7
Water (ml)	40
Agar (g)	1.6
Soap (ml)	6

Recipe

1. Add agar, water and glycerine into a pot.
2. Cook over medium heat and stir until the solution starts to boil and becomes viscous.
3. Add liquid dish soap and then whisk the solution until it all becomes foam.
4. Tape down a wooden frame on a non stick surface and pour in the foam.
5. Let the bioplastic dry according to the previously stated steps.

*The mixture of corn starch and water is a dilatant, non-Newtonian material that thickens when a force is applied. Foam was not achieved with Corn Starch bioplastic because, even with soap, when the solution was whisked it increased in viscosity and bubbles did not form.

Gelatine+Clay

Animal Based Bioplastic with Red Ochre Clay

Ingredients

Recipe	Brittle	>		Flexible
Glycerine (g)	0.0	1.5	3.0	6
Water (ml)	60	60	60	60
Gelatine (g)	12	12	12	12
Clay (g)	5	5	5	5

Recipe

1. Add gelatine, water, glycerine and clay into a pot.
2. Cook over medium heat and stir for 4 minutes until the gelatine is dissolved and the solution thickens.
3. With a spoon remove any froth, so that the bioplastic will have a glossy, smooth surface.
4. Tape down a wooden frame on a non stick surface and pour in the solution.
5. Let the bioplastic dry according to the previously stated steps.

The Red Ochre used in the bioplastic mainly consists of clay and iron oxide, Fe_2O_3. Ochre can range from hues of yellow to red to brown, and the red variety comes from the presence of dehydrated iron oxide. On their own, ceramics, such as red ochre, have low toughness and are extremely brittle. Adding red ochre to bioplastic creates a composite material which benefits from the combined properties of both materials. The bioplastic will increase the toughness of the composite and the crystallinity of the ceramic will increase the stiffness of the composite.

Agar Agar+Clay
Plant Based Bioplastic with Red Ochre Clay

Ingredients

Recipe	
Glycerine (g)	2.7
Water (ml)	40
Agar (g)	1.6
Clay (g)	5

Recipe

1. Add agar, water, glycerine and clay into a pot.
2. Cook over medium heat and stir until the solution starts to boil and becomes viscous.
3. Tape down a wooden frame on a non stick surface and pour in the solution.
4. Let the bioplastic dry according to the previously stated steps.

Corn Starch+Clay
Plant Based Bioplastic with Red Ochre Clay

Ingredients

Recipe	
Glycerine (g)	5
Water (ml)	130
Corn Starch (g)	15
Vinegar (ml)	15
Clay (g)	5

Recipe

1. Add corn starch, water, glycerine, vinegar and clay into a pot.
2. Cook over medium heat and stir for 10 minutes. Continue to heat after the solution becomes viscous to evaporate the excess liquid.
3. Tape down a wooden frame onto a non stick surface. Spoon a thin layer of the mixture into the frame (if it is too thick it will crack as it dries).
4. Let the bioplastic dry according to the previously stated steps.

Gelatine Foam
Animal Based Bioplastic with Soap

Ingredients

Recipe	Brittle	>		Flexible
Glycerine (g)	0	15	30	60
Water (ml)	60	60	60	60
Gelatine (ml)	45	45	45	45
Soap (ml)	6	6	6	6

Recipe

1. Add gelatine, water and glycerine into a pot.
2. Cook over medium heat and stir until the gelatine is dissolved and the solution starts to thicken.
3. Add liquid dish soap and then whisk the solution until it all becomes foam.
4. Tape down a wooden frame on a non stick surface and pour in the foam.
5. Let the bioplastic dry according to the previously stated steps.

Foam is created by trapping air in a solid or liquid, which requires mechanical work and surfactants.
Work: By whisking, (doing work) the surface area of the solution increases and air is dispersed within the liquid.
Surfactant: Liquid dish soap is a surfactant. It's molecules naturally form bubbles (micelles) with their hydrophobic tails in the center, and their hydrophilic heads on the outside where they are attracted to the water-based bioplastic solution. Surfactants help to stabilize foams because they increase the elasticity of the solution, allowing bubbles to be agitated without rupturing.