

BIOPLASTICS KIT **BETA**

MAKE BIOPLASTIC USING FOOD WASTE



BIOPLASTICS KIT™

REUSE FOOD WASTE

instruction manual

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Welcome! Let's get started



This user guide was created to help you get the most out of your Amino Labs experience. Even if you are familiar with making new materials, bioplastics, science or other Amino Labs™ products, please take the necessary time to read through this guide. This will ensure you practice safe science as well as store, use, and get the most out of your kit. It will also let you know what to do in case of a spill or accident.

In the first section, you will learn about your kit's components, how to store them before and during your experiment, as well as a few tips on activities to complete before you get your hands 'wet'. The second section is procedural -- these are the step by step instructions on how to run your experiment. Make sure to follow our tips to ensure your best success! The third section covers "what's next"; how to keep your creations, store or dispose of any leftover ingredients and general clean up instructions. The final section is there to help you -- a glossary, troubleshooting, and our contact information.

Amino Labs is excited to welcome you to the world of Bio-design with the Bioplastics kit! The first in a series of experiment to get you making with biology! **Following this guide will help ensure that you are getting the most out of your current and future experiences to keep on making new creations. Have fun!**

Practicing safe science - Bioplastics

Science is a safe activity when you follow simple guidelines. Read on to ensure you adopt safe practices.

The kit in your hands contains only inert ingredients - no live organisms. The ingredients are all safe to use without any special containment or training. Most of the ingredients will be familiar to you from your kitchen. Even though these are familiar, you should never eat or taste any part of this kit, or any ingredients you use for science experiments. Follow these safety guidelines for your safety and the success of your experiment(s)!

We recommend the system and kits for ages 12+, under adult supervision, and 14+ with or without supervision. The cleaning instructions must be strictly followed for safety and experiment success. Make sure to store the kit per the instructions found in this booklet.

- **Do not eat or drink near your experiments.** Keep your experiment at least 10 feet from food, drinks, etc. Under no circumstances should you eat any of the kit's content.
- **Wash your hands before and after** your experiment,
- **Wear gloves**, is recommended even when cleaning your station or handling the kit contents as part of a safe science practice. This will protect you from your experiment, and your experiment from you. Any latex, nitrile, or general purpose gloves you can find at the pharmacy will do. After you put your gloves on, be aware of what you touch. Try not to touch your face or scratch itches with your gloved hands!

- **Clean up your work station, spills and work surface before and after use.** Use a 10% solution of chlorinated bleach generously sprayed onto a paper towel and rub onto any contaminated surfaces. (Careful! This can discolor your clothes). A chlorinated spray cleaner also works.
- With the Bioplastics kits, all the discarded materials can go in the garbage. **Do not pour bioplastic mixture down the sink.** Find a container to hold the inactivation bag where you will discard used items. If you are familiar with other Amino Labs kit, you can use a discard container at your station to hold all your materials, just like when doing your genetic engineering experiments.
- **Eye-wear is not provided but can be worn.**

While these also include rules specific to experiments with live organisms, you can still download a biosafety poster for your space from www.amino.bio/biosafetyinaction and complete a short safety quiz at www.amino.bio/biosafety-quiz

If you would like to do a short Online lab safety course for your edification, we recommend a Government of Canada course: www.amino.bio/biosafety

Discover your Bioplastics Kit™

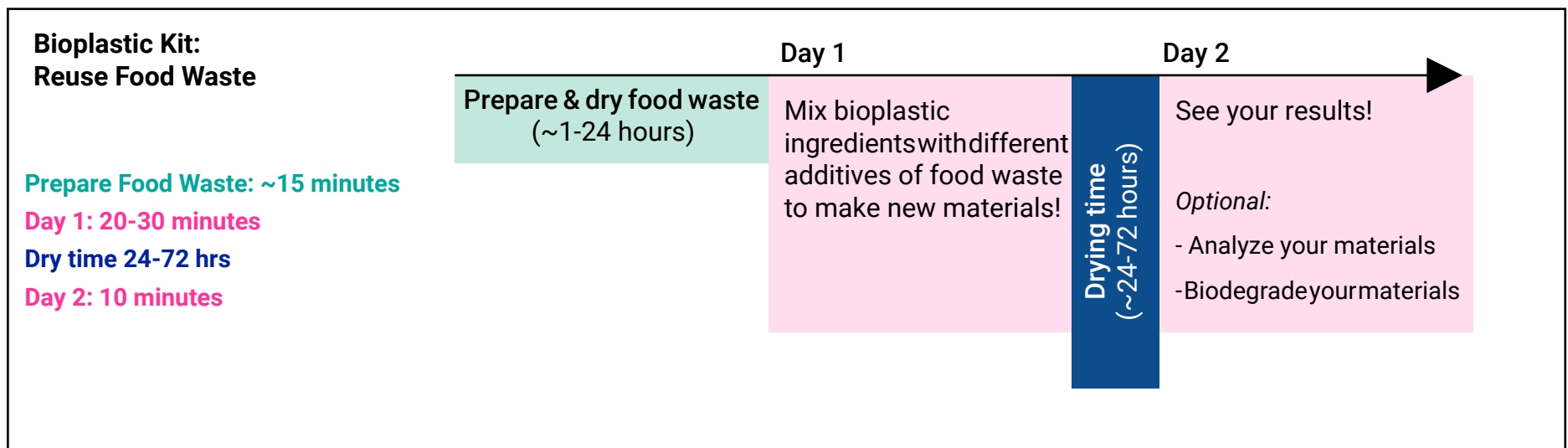
With the Bioplastic Kit series, you'll learn to combine biological ingredients to create new materials: bioplastics. With this specific kit, you'll be adding food waste to the bioplastic recipe to create what are called **biocomposite**. One food waste is included in the kit, and you will have to find another at your home or school. Page 8 has more information on what to look for and how to prepare.

This kit can be used alone or in a small group (adult supervision if you are 14 or under). Follow the instructions on the next pages to:

- discover some ingredients used in bioplastic: pectin, acetic acid, gelatin glycerol, and water,
- gain or improve your making skills like mixing, measuring, casting bioplastics.
- learn how to add renewable resources like food, agricultural or industrial waste to your bioplastic to change their properties. These additive, called fillers or bio-fillers, are often used in industry to bring additional properties to the final material.

Timeline

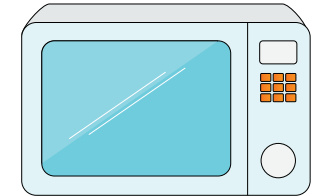
The experiment will take between 15 and 30 minutes. Then, you will have to let your bioplastics dry, for ~72 hours, depending on your location. By placing the drying plastics in a hot, dry location you can speed up drying.



Unpacking and storing kits

For a better shelf life and a successful experiment, place your kit at **room temperature**, away from the light.

Items you will need



- **Access to a microwave**
- **Marker or pen**
- **Paper towels for clean up**
- **A mixing utensil** like a spoon (metal, plastic or wood is ok!)
- **Distilled or tap water** (~100 mL)
- **~5g of food waste** like dried fruit peel, egg shells or used coffee grounds. Place in a bag to crush them into a powder when dry. (See page 9 for more information)

Necessary safety supplies



- **Optional: Latex/nitrile gloves** like those found at a pharmacy. 1 pair/person if you reused them, or 5 pairs/person.
- **Soap and/or spray cleaner** bottle for cleanup

Kit components

Tube of oil: This tube of vegetable oil will help you lubricate your mold and containers to easily take out your bioplastics once dry. If you make bioplastics outside of this kit, you can use household oils, like olive, canola or coconut as mold lubricant (also called mold release).

Tube of glycerol: Glycerol (sometimes also called glycerin) is a colorless, viscous liquid that helps soften and reduces shrinkage in bioplastics. This is because glycerol functions as a plasticizer that bonds with the polymer in your mixture. A plasticizer is something that is added to another material (usually a plastic base) to make that material softer or more pliable.

Bottle of 5% Acetic acid solution: Acetic acid is a clear, colorless, organic liquid with a pungent odor similar to household vinegar. Indeed, acetic acid is the main component of vinegar which is around ~4% acetic acid. Adding acetic acid breaks up some of the polymer chains, making the plastic less brittle.

Gelatin: Gelatin is a colorless powder derived from collagen, which acts as a binding material and a hardening component in bioplastics. It often functions as the polymer in your mixture.

Pectin: Pectin is colorless powder obtained from fruits and plants. It is a polysaccharide starch that functions as the polymer in your mixture. It is also what gives jelliness to jams!

Chitosan: Chitosan is a subproduct of chitin. Chitin can be found in a big range of living organisms like sea animals, insects and microorganisms, but is mostly extracted from crab and shrimp shells. It is a natural, extremely abundant polymer and the main component in the cell walls of fungi and gives the structure to the exoskeletons of insects and sea creatures. Chitosan is one of the most important subproducts of chitin created when chitin goes through a process called deacetylation. This enables the new product, chitosan, to become soluble in acidic solutions while retaining similar structural properties of chitin. This is helpful as chitin itself is insoluble in most readily available solvents.

Petri dishes bag: You will use these petri dishes as molds in which you will dry your different bioplastic mixtures.

Beaker: A beaker help you measure and heat the water you need to make your bioplastics, and to mix your ingredients in.

Before you start:

Collecting some food waste to use as a “filler”

For one of your bioplastic recipe you will need to add dry food waste from your own kitchen or cafeteria. This is called a filler in the bioplastic. Many different food/agricultural waste can be used. We recommend using fruit/vegetable peels like those of an orange or potato, egg shells or used coffee grounds. You will need to dry and crush them before use.

You will need ~3 tablespoons of dried and crushed food waste for this experiment.

To dry the food waste:

To air dry your food waste, leave the peel/grounds/shells to dry at room temperature (near a hot vent works well) until they are fully dry and easy to crumble. This can take up to 48 hours.

To oven dry, set your oven to 250 degrees Fahrenheit and lay the food waste on a clean cookie sheet or similar (do not grease the cookie sheet). Let your food waste dry in the oven for a total of 1.5 hours. If possible, flip it after 45 minutes so that it dries evenly. If you are using egg shells, you can place them in boiled water for 10 minutes to clean them before you dry them.

To crush/powder the food waste:

If you have a mortar and pestle or spice grinder, you can use it to turn your food waste into powder. If you don't, no problem! Take a plastic bag, add your dry food waste and close it tight. Take a bottle, rolling pin, or cylinder object and roll over the bag back and forth until you get a powder. Make sure the food waste is dry before you do this, otherwise it will be hard to powderize!

The Big Plastic Problem & bio-based plastics

Plastics are a well-known material that is used to make our modern world go round. There is a high probability that you have many types of plastics around you right now. Can you spot them? You may see an appliance, electrical cord, clothing, shoes, pet food or water dish, or a garbage bin. You'll likely notice many types of plastics with many different properties. But did you know that all plastics have a similar basic chemical structure?

What are plastics?

Plastics are chains of repeating molecules linked together. These “strings” of repeating molecules are called polymers. Since these chains are called polymers, plastics are also often called polymers. You might have noticed that many plastic names start with “poly.” Now you know why! Different plastic properties are a result of the types of atoms and molecules that make up the polymer chains. These repeating molecules can either all be the same (also called a monomer) or by a few different molecules that repeat in a pattern (a true polymer).

The process of creating plastics is called polymerization. During polymerization, the smaller molecules, called monomers or building blocks, are chemically combined to create the polymers. The first “modern” plastic was Bakelite, a material that could not be melted again when formed. Bakelite was introduced in 1907 by chemist Leo Hendrik Baekland. He also coined the term ‘plastics’ to describe this new category of material. Since the introduction of plastics, most polymers have been produced with petrol-based compounds because petroleum-based compounds are cheap, easy to obtain and process, and very durable.



Bakelite buttons. Source: Science History Institute, CC BY-SA 3.0, via Wikimedia Commons

Just what is the Big Plastic Problem?

You are probably aware that many scientists, innovators, and students like yourself are now looking to biology to solve the big plastic problem. But why? Traditional plastics have three significant impacts on the environment: they use fossil fuels, have a large carbon footprint, and stay in the environment for hundreds of years. One major problem with plastic that needs to be addressed right away is that it is too durable! Most petroleum-based plastics are not biodegradable; instead, they degrade so slowly that they stay in the environment, landfills, beaches, and oceans for decades up to hundreds of years. While several factors impact the timeline to degrade plastics, like the polymer it is made from and the environment it is discarded in, on average, single-use plastic bottles will take about 450 years to degrade, while a plastic bag can take anywhere from 10 to 1,000 years to degrade in a landfill!

Unfortunately, the problem doesn't end here. As we continue to learn about the presence of plastic in the environment, science indicates that some of these petroleum-based plastics do not entirely go away. If they are not recycled into new plastic products, petroleum-based plastics like PVC will break down into smaller pieces that stay in our environment, water systems, and soil. These are sometimes referred to as "forever plastics" or microplastics, and they've been found in all our oceans, marine life, drinking water, and even in human bodies! While the impacts of these microplastics on living organisms, plants, animals, and human health are still being studied, there is just no escaping them. Scientists have seen microplastics in most places they have looked: In deep oceans, in Arctic snow and Antarctic ice, in shellfish, table salt, drinking water, human blood, and even drifting in the air or in the rain.

This is why more and more people are looking at ways to degrade existing petroleum-based plastics. Others are working to create new types of plastics made with biological materials that can degrade quickly, do not rely on fossil fuel as a source of the monomers, and have a smaller carbon footprint.



Plastic debris disintegrates over time into smaller particles of various sizes and shapes under natural processes like UV radiation and mechanical abrasion. These are referred to as secondary microplastics and form more than 80% of microplastics found in the environment. Source: Oof.cc, CC BY-SA 4.0, via Wikimedia Commons



Gelatin-based bioplastics dyed with algae extract.

What are bioplastics?

These new types of plastics made with biological-based ingredients are called bioplastics. Early research indicates that they could be a significant improvement over petroleum-based plastics. To clarify, bioplastics are plastics made at least in part with renewable biological matter (like vegetable fats and oils, corn starch, wood chips, sawdust, and food waste), or they are plastics that can degrade in a reasonable time.

It might surprise you to learn that bioplastic production is much older than the petrol-based plastics we use today! In 1500 BC, people in Egypt were already using materials made of gelatin and casein (a protein found in milk) for furniture constructions. And it's not all ancient history either; in the 1940s, industrial pioneer Henry Ford experimented with soya bean plastics. Cool! The history and potential of bioplastics are rich and inspiring.

Today, bioplastics are being developed and tested as sustainable replacements for single-use plastics for packaging, utensils, food containers, 3D printing, fashion, and even medical implants. But since bioplastics have different properties than their petroleum-based counterparts because they are mostly made from biodegradable ingredients, it can require an innovative mindset to use them industrially. For example, since some bioplastics use ingredients that can dissolve in water, the plastics themselves can also dissolve in water! This property can be an advantage in some situations, but it can also limit its use. For example, bioplastic utensils and bowls that dissolve in contact with liquid will not help bring hot leftovers home and eat them. Like any technology, bioplastics will have their ideal use cases, current limitations, and potential for improvements.

And it is now your turn to join bioplastics innovators! Let's learn how to make bioplastics. Further, you'll learn about some typical bioplastic ingredients and how bioplastic properties compare to the traditional plastics you already know.

Recommended pre-labs

Amino Labs has many resources that can be used in a classroom or at home before you complete the experiment to maximize understanding and success.

1. Virtual Simulator - Bioplastic Kit Edition

<https://amino.bio/pages/bioplastic-experiment-simulation>

Use the Virtual Bioengineer: Bioplastic Kit simulator to learn how to make different bioplastics! You'll start with learning a basic bioplastic recipe's ingredients, then you'll be able to practice making different things with the bioplastic, including the strings and sequins from this kit! The simulator takes approximately 15 minutes to complete.

If you are an educator, you can use the simulator during class as a group presentation or have students complete it as a homework/in-class assignment.



2. Classroom presentation & lesson guide with activities

<https://wiki.amino.bio/Resources/By-Kit/Bioplasticskit>

1-3 class lesson & classroom-ready presentation including follow-on activities, classroom-ready slides to introduce the subject (with fun examples in the real-world) and to guide the experiment and discussions.

If you are an educator, keep an eye on this link, as any new Bioplastics lessons and activities will be added there first!

A key pitfall to avoid!

In the next pages are detailed, step-by-step instructions to complete the experiment. **It is helpful to read through all of the steps for each part of the activity before starting that day's activity.**

While all the steps outlined in the experiment are important and should be followed as described, **the MOST IMPORTANT consideration for success is:**

Always make sure that the water is boiling before adding any powder or liquid to make sure the ingredients will fully dissolve.

You have to see the water bubbling! Be careful, the bottle or bowl will be hot!

Experiment Protocol

Prepare your space

Goal Set yourself up for success.

Materials from the kit

Materials not in your kit

Spray cleaner
Paper towels
Pair of gloves



Make sure you have the necessary materials as described on page 6, including access to a microwave and water before you start. Also make sure that you have read and understood the safety guidelines.

1. If you have them, put on your gloves and an apron or lab coat.
2. Remember that you can dispose of used items in the garbage but that **you should not pour liquid bioplastic mixture down the drain as it could solidify in the drain.** When you are ready to dispose of your used bioplastics or any extra mixture, you can let it dry before scooping it out into the garbage, or you can pour it directly in a garbage bag.
3. Choose a work surface that is stable, non-porous and easy to wipe (non-porous surfaces are smooth and sealed so liquid cannot go into them, like glass, plastic, varnished wood). Wipe down your work surface with a spray cleaner before starting
4. You will need to let some of your bioplastics dry for up to ~72 hours in the molds provided in your kit. Once the hot bioplastics are poured into the molds, try to avoid moving the containers for about 20 minutes until the mixture solidifies. This will help avoid spills. After that time, the mixtures will be solid enough for you to move the molds to a more convenient location for longer-term drying.

1. Make a bioplastic (biocomposite) with Chitosan

Goal Create a bioplastic by reusing industrial food waste

Materials from your kit

1x tube of oil
1x packet of gelatin (1 g)
1x packet of chitosan (3g)
1x tube of glycerol (2mL)
1 large petri dish
Beaker

Materials you provide

1x Mixing utensil
25mL Water
Microwave, Paper towels, Marker/pen

Today, you will explore biocomposites, materials made from a mix of bioplastic and renewable fillers like food and agricultural waste. They are a good alternative to traditional petroleum products since they can gain the properties of both the bioplastic ingredients and the filler.

For your first biocomposite experiment, you will add the chitosan powder from your kit.

What is Chitosan?

Chitosan comes from chitin, which is an industrial food waste created in the process of shellfish. Chitin can be found in a big range of living organisms like sea animals, insects and microorganisms, but is mostly extracted from crab and shrimp shells. It is a natural, extremely abundant polymer and the main component in the cell walls of fungi and gives the structure to the exoskeletons of insects and sea creatures. Chitosan is one of the most important subproducts of chitin created when chitin goes through a process called deacetylation. This enables the new product, chitosan, to become soluble while keeping similar properties of chitin.

Prepare your molds (petri dish)

You will be using both sides of the petri dish (lid and bottom) to dry your bioplastics. Prepare them both now.

1. Take the smaller/thinner of the two half of the petri dish. This is your mold for Chitosan bioplastic. Use a marker to write Chitosan on the outside.
2. On the larger half, write the name of your food waste. This will be your second mold.
3. Pour a small amount of oil inside each mold and rub it around use it to coat the entire inside of the mold. This will act as a mold release.

Make the Chitosan bioplastic

4. Using your beaker, measure **25 ml** of water.
5. Add your tube of glycerol (2 mL) and one packet of gelatin (1 g) into the beaker.
6. Microwave this until you see the liquid boil.
7. Pour the entire contents of the chitosan (3 g) bag into the beaker.
8. Stir until the mixture is smooth. You can microwave for another 10 seconds if the mixture is clumpy. Repeat microwaving and stirring until your mixture is smooth.
9. Pour your mixture into the “Chitosan” petri dish. You’ll want to pour the entire mixture into the mold. Use a paper towel to clean any that spills.
10. Leave it on the side to dry.

2. Make a bioplastic (biocomposite) with your own food waste

Goal Create a bioplastic by reusing domestic food waste

Materials from your kit

1x packet of gelatin (1 g)
1x packet of pectin (1.25 g)
1 petri dish as mold
Beaker

Materials you provide

1x Mixing utensil
3 tbsp of dried and crushed food waste
Microwave, Paper towels, Marker/pen

For your second biocomposite experiment, you will add the food waste filler you collected, dried and crumbled. (Page 8)

Make your food waste bioplastic

1. Add all of the 5% acetic acid from the bottle to your beaker. Acetic acid smells very strong! Keep it away from your eyes/face.
2. Add the packet of pectin (1.25 g) and one packet of gelatin (1 g) into the beaker.
3. Microwave until you see the liquid boil. Careful as the odor will be stronger when hot!
4. Add 3 tablespoons of your dried and crushed food waste into the beaker.
5. Stir until the mixture is smooth. You can microwave for another 10 seconds if the mixture is clumpy. Repeat microwaving and stirring until your mixture is smooth.
6. Pour your mixture into the remaining mold. You'll want to pour the entire mixture into the mold. Use a paper towel to clean any that spills.
7. Leave it on the side to dry.
8. Wash the beaker and mixing utensil with hot water and soap. Dry with a paper towel.

Dry your bioplastics and learn from your experiment

9. Dry both bioplastics for 24 to 72 hours at room temperature, or until no longer sticky to the touch. Once dry, remove them from the mold gently as they can be fragile.

Curious how other food wastes would influence your bioplastic? You can explore using with different materials like corn husks, sawdust, straw, and different sizes of filler like fine and coarse powder, granular, or even 1 cm size pieces in your mix. To repeat at home, you can use vinegar and store bought pectin/gelatin, or get a Bioplastic ingredient refill kit from www.amino.bio.

Head to the Glossary at the end of the manual to learn more pectin, acetic acids, and fillers. The next two pages contain optional activities to help you learn even more about your creations: What are their material properties? And are they biodegradable?

3. Analyze Material Properties

Goal Create a bioplastic by reusing domestic food waste

Materials from your kit
Your dried bioplastics

Materials you provide
Printer or computer for the analysis sheet

Do you notice any special properties transferred from the food waste fillers to the bioplastic? Let's analyze them to find out!

You will need to print or make a copy of the Material Properties Table at www.amino.bio/bioplastics-analysis-foodwaste

Prepare your bioplastic for analysis

1. Remove your bioplastics from their containers once they are dry (no longer gel-like to the touch). Peel them up slowly and gently. If the bioplastic is hard to grab, run a flat utensil (such as the end of your mixing spoon) or your gloved fingers between the edge of the bioplastic and the container.

Analyze your bioplastics

2. Use the Material Properties table at this link to evaluate your samples: www.amino.bio/bioplastics-analysis-foodwaste
3. Based on your material evaluation, can you identify which properties relate to which ingredient? Fill out your observations in the Ingredient Properties Table.
4. Learn more about the properties of each ingredients by going to the glossary at the end of this instruction manual.

Degradability

Degrade your bioplastic(s) in water and/or in soil

Goal Can we degrade some of our bio-plastics so they leave no trace in the environment?

Learn from your experience

Now that you've experimented with and analyzed bioplastics, you may be curious as to what happens to bioplastics once they have fulfilled their purpose. You'll remember from the introduction that the term bioplastics refers to a broad category of materials that includes bio-based plastics like the ones you created; a bio-based plastic can either be fully made from biological matter (like the ones you made), or partly made from biological materials. Confusingly, bioplastics can also refer to plastics that are biodegradable, whether they are made with bio-based ingredients or not. Let's see if we can make sense of all these terms.

A biodegradable plastic is a plastic that can be broken down by microorganisms in a reasonable time frame. While all plastics can eventually degrade once thrown away, we saw earlier that for most of the plastics we use, it can take decades, hundreds or thousands of years before this happens. As they degrade they can create microplastics that linger in the environment for even longer, possibly forever.

Biodegradable plastics aim to resolve this issue by ensuring that microorganisms can break down the plastics quickly. Beyond biodegradable plastics, you can also find **photo-degradable plastic** which are mostly petroleum-based plastics to which chemicals are added to help them break down faster in the presence of sunlight. Other additives can be added to help plastics degrade in water (**hydro-degradable plastics**), or through oxidation, so by reacting to the oxygen in the atmosphere (**oxo-degradable plastics**).

Which category of bioplastics do you think our bioplastic experiments fall under? Are they bio-based? Biodegradable? Photo-degradable? Oxo-degradable or even hydro-degradable?

The plastics you made are definitely bio-based because all their components derive from biological material. We did not add any special chemicals to help them degrade in the presence of oxygen, or in the presence of sunlight, so they are neither photo-degradable nor oxo-degradable. However, it is likely that our plastics could be hydro-degradable since most of the ingredients we used to make them are soluble in water. It is also possible that they are biodegradable since most of the ingredients we used come from organic matter. Why not test out our hypothesis?

If you'd like to test the biodegradability and/or hydro-degradability of some of the plastics you created, have a look at the next two activities which will show you how to test your bioplastics degradability in water and in soil. You can try one or both of these methods with the bioplastics you have. Cut them in half to try both. Keep in mind that this last experiment can take weeks or months before you see results. If you are ready to end the experiment now, or at any point in the future, just skip ahead to the "Storage, disposal and clean-up" page.

Are bioplastics hydro-degradable?

4. Degrade your bioplastic(s) in water

Goal Can we degrade our bio-plastics in water so as to leave no trace?

Materials you provide

Paper towels

Marker/pen

Your bioplastics

Mixing beaker

~400 mL of water

Degrade your bioplastics in water

When plastics ends up in the ocean or other water bodies, the water is much cooler than the water we used to make them. Let's test if your bioplastics would dissolve in room temperature water.

1. Add 400 mL of tap water in your beaker.
2. Choose one or more of your bioplastic you want to test for hydro-degradation. You can cut them in half if you also want to test their degradability in soil.
3. Weigh the sample before you add it to the water. Note the measurement in the table below, alongside the time and day you start your degradation experiment.
4. Add your sample to the water. Your experiment is underway!
5. We recommend taking your sample out of the water every 2 or 3 days to weigh it and take notes on it, until you can no longer collect it from the water.

Hydro-Degradation Bioplastic Experiment Table									
Material sample: _____									
Time / Date									
Weight									
Notes									

Verify your water for the presence of plastics.

6. If/when your water looks clear, take your last measurement and notes (you can mark the weigh as 0 if there is no sample left).
7. Is there any plastics left behind? You can verify by pouring the water through a coffee filter or paper towel as you dispose of it.

What did you find? You can share your findings with us!

Are bioplastics biodegradable?

5. Degrade your bioplastics in soil

Goal Can we degrade our bio-plastics in soil, so as to leave no trace?

Materials you provide

Paper towels

Marker/pen

Your bioplastics

A small shovel/garden trowel or similar

A location where you are allowed to dig a small hole in dirt

A marker for the location you chose to find it again

Degrade your bioplastics in soil

Because our bioplastics are mostly made with food-like ingredients, we can hypothesize that they would biodegrade in a reasonable time frame. Temperature, humidity and soil organisms all play a role in the biodegradable process. Let's see if we are correct in assuming our sample(s) will biodegrade and what that time frame would be.

1. Choose the bioplastic(s) you want to test for biodegradability.
2. Weigh the sample as it is now. Note the measurement in the table below, alongside the time and day you start your degradation experiment.
3. Dig a small hole in the dirt of your yard, or any location you are allowed to use. You will need a hole about 4 inches across and 2 to 4 inches deep. You can also fill a large container with soil if that's easier.
4. Place your sample in the hole, and cover it with dirt. Identify the location with a marker - if you are in a private yard, a large rock or stick can work. If you are in a public location like a school yard, you can make a small sign to announce your experiment location, as long as you have permission. Your experiment is underway!
5. If you can, we recommend taking weight measurements and notes on the plastic sample and soil condition every week. Depending on the environment, soil, and temperature where you test, you may need to extend this table to add more columns if your bioplastics take longer to degrade.

Biodegradability Bioplastic Experiment Table									
Material sample: _____									
Time / Date									
Weight									
Notes									

Analyze your results.

6. Are you noticing any weight decrease in your sample? Can you make a graph that predicts when the sample will be fully degraded after you've measured for a few weeks? What did you find? You can share your findings with us!

CONGRATULATIONS



You have now joined the global community of bio-designers and material innovators! Happy with your results? There are many opportunities to share it online and in your community. You can also share your results with friends and our growing community: find us on Instagram, Twitter, TikTok and Facebook @aminobiolab

Now, let's make sure you dispose of and store your remaining material correctly.

Storage, Disposal, Clean Up

After you see your results and end the experiment, it is time to clean up, dispose of and store away your materials. Disposing of experiment materials is an integral part of experimental protocols.

A. Preserving your bioplastic(s): If you want to preserve your bioplastics for future reference, you can place your samples/work with an identifying labels in a container. Or, you can attach them in a binder along with any experiment notes and material property analysis.

B. Disposing of your bioplastics: If you would like to dispose of all or some of your bioplastics samples, you can place these in the garbage, melt them down, or place them in the compost pile. Unfortunately, the bioplastics you've made cannot go into the traditional recycling stream as the recycling industry is not ready to deal with these.

C. Disposing of your other kit material: All tubes, bottles, containers and plastic packaging can be disposed of in a recycling bin or garbage. Of course, they can also be washed and kept for reuse. Wash with soap and water and kept for reuse around the house/classroom.

D. Unused ingredients/items: If you did not use all of your ingredients, you can keep them in a sealed bag for reuse later. If the ingredients are in powder form, make sure the lid of the container/tube is tight to prevent the powder from humidity. Do not eat or cook/bake with any of your science kit ingredients!

E. Clean your workspace: Use a spray cleaner, wipes, or hot, soapy water to clear up your work area and equipment. If you are using a bleach cleaner, always wear gloves and remember that the bleach cleaner can discolor clothes and fabrics.

Bioplastic Glossary

Acetic acid: You'll have noticed that acetic acid is a clear, colorless, organic liquid with a pungent odor similar to household vinegar. Indeed, acetic acid is the main component of vinegar apart from water and trace elements. Regular vinegar is around ~4% acetic acid.

Acetic acid has a variety of uses, including as raw material and solvent in the production of other chemical products, oil and gas production, and in food and pharmaceutical industries.

The acetic acid in the recipe helps the starch fully dissolve in the mixture because starch dissolves better in the presence of electrically charged ions which the acetic acid provides.

Large cellulose molecules, like starch, are long-chain polymers. In this experiment, two ingredients change the properties of the polymer plastic. By adding a small amount of acetic acid, you break up some polymer chains, making the plastic less brittle.

Algae/Agar Bioplastic: Agar is a yellowish powder that comes from algae. It acts as a binding material and a hardening component in bioplastics. In addition, it functions as a polymer in bioplastic mixtures.

Agar is a polymer created from the agarose and agaropectin found in the cell walls of red algae. It is often used as a vegetable replacement for gelatin. It is used as a thickening or gelling agent in cooking. However, agar is more flexible than gelatin. You can combine gelatin

powder with agar powder to make a more flexible/hybrid material.

Agar bioplastics are a suitable replacement for disposable single-use packaging, including snack packaging and dry food packaging. And, if you've done any biotechnology or microbiology, you'll recognize agar from the substrate that microorganisms grow on. It's the same ingredient, used differently. A fun fact about agar: it affects touch capacitive screens! You might be able to make an agar bioplastic stylus for your tablet!

For agar to work successfully, it first needs to absorb water which it does by being brought to a boil (100°C) It becomes a gel at room temperature since it solidifies at 32–40 °C. Solid agar gels will start melting at 85 °C.

Agar does not hydrate (absorb water) well in acidic liquids, making gelling difficult. To use agar alongside an acidic bio-plastic ingredient, first hydrate the agar in water, allowing it to dissolve, before adding it to your acidic ingredient.

Agar shrinks a lot in size and thickness over time, and if left in a mold where it's connected to wooden edges, it will form cracks in the center. So make sure to cut the agar free from the edges of the mold after the first 24 hours of setting.

Agar bioplastic should decompose for two months in summer temperatures, taking approximately four months in cooler climates.

Biocomposites bioplastic: Biocomposites are made from a matrix of plastic and renewable fillers. Biocomposites can be made entirely of bio-based ingredients (biocomposite bioplastics) or with bio-fillers to replace some of the petroleum-based content of traditional plastics. In adding bio-fillers to traditional plastics, non-renewable ingredients can be drastically reduced.

Bio-fillers: are organic materials that are ideally waste by-products of other industrial processes like agriculture or paper processing and combined into plastic recipes to provide different properties or limit the number of other ingredients. They are sometimes referred to as biomass. Fillers can help the material keep its shape and reduce the natural shrinkage in most bioplastic.

You can use different bio-fillers in biocomposite to obtain different materials properties. Popular bio-fillers are dried peels, eggshells, dried plant leaves, shredded paper waste, seafood wastes like shells, starch, or wood dust. You can add natural colorant by choosing naturally colorful bio-fillers.

You can also try to mix in your bio-filler to a gelatin-glycerol bioplastic recipe instead of a pectin recipe to obtain different properties.

Drying: when a material dries, it can shrink and deform as the water leaves the mixture. You can remedy this by placing heavy objects on your drying plastic to compress it into the desired shape. You should always dry your bioplastics indoors and away from direct

sunlight and pets, insects, and younger siblings. While many ingredients in bioplastic can be found in foods, you should never eat any of your experiments.

Gelatin: is a colorless powder derived from collagen. It acts as a binding material for bioplastic mixture and a hardening component. It also provides transparency to the piece. Gelatin functions as a polymer in bioplastics.

Gelatin bioplastics are clear, strong, oxygen permeable, and hygroscopic. The properties of gelatin bioplastics are influenced by drying temperature. When Gelatin bioplastics are dry, especially when exposed to the sun, they often get quite brittle. Even when adding more glycerol to the recipe, it is still one of the stiffer bioplastics to work with. Gelatin bioplastics can also be heated up or whetted to shape them over forms/molds and melted back down for reuse.

Gelatin is primarily used as a gelling agent in food, pharmaceutical, and cosmetic industries. When it comes to gelatin bioplastics, they can be used for alternative packaging, to create a folder/pocket, to replace stiff plastic materials you might use in your daily life.

Gelatin is often an animal-based ingredient. Some might find it problematic to use resources that require killing an animal because of religious or animal welfare beliefs. Arguments are also made that as long as there's a meat industry, it is better to use products from the entire animal, including skin and bones. Some might consider gelatin a product that comes from a waste stream, but this is considered controversial by others. To avoid using animal-based gelatin, use agar or vegetarian gelatin.

Glycerol: is a colorless viscous liquid that helps give shape, softens, and reduces shrinkage in bioplastics. Glycerol functions as a plasticizer that bonds with the polymer in your mixture. Sometimes also called glycerin, although glycerol is a pure form, while glycerin is a mixture that contains 95% glycerol.

Glycerol is a sugar alcohol derived from animal products, plants, or petroleum (as a by-product of bio-fuel). It can also be obtained from micro algae oils, and it can be recovered from used cooking oil.

Glycerol has a low melting point (18°C) and high boiling point (290°C), which makes it suitable as a plasticizer in bio-materials. As a plasticizer, glycerol “lubricates” the plastic. If you want the plastic more pliable, add more glycerol. If you want the plastic to be stiff, add less glycerol. However, higher glycerol concentration makes the bioplastic weaker (low tensile strength), more fragile, and easier to degrade under wet and dry soil. But the flexibility of your glycerol bioplastic will make it easier to peel them out of their drying containers.

In biomaterials, glycerin can be used as a plasticizer for more flexible bioplastics, as moisturizer or softener in tanning (e.g., bacterial cellulose), as an additive for bubbling textures/mixes, and as a solvent for pigment extraction. It has antimicrobial properties.

Material sample: in general, a sample is a limited quantity of something intended to show what the whole is like. A material sample of bioplastic is then a small piece of bioplastics that you can use to understand how a larger quantity of the material would behave and be useful for.

Material samples library: is a resource for material research, exploration, and experimentation consisting of an expanding collection of material samples, analysis, and notes.

Mold: a mold is a hollowed-out shape filled with a liquid or pliable material like plastic, glass, metal, or ceramic. The liquid hardens or sets inside the mold, adopting its shape. Molds are sometimes called forms or negative forms and are often used to replicate a “master” item. The mold you select will affect both the shape of your material as well as the drying process. For example, thicker materials will take longer to dry.

Pectin Bioplastic: You may have heard of pectin before and might even have made some while making jams. Pectin is a colorless powder typically obtained from fruit. It is a polysaccharide starch found in the cell walls of fruits, vegetables, and plants - it is the second most abundant component of the cell wall of all land plants. Pectin functions as the polymer in bioplastic mixtures and is what makes jams jelly!

Pectin is often used as a gelling agent in desserts, but it also has wide applications in various fields due to its use as a gelling, emulsifying or stabilizing agent and its non-toxic, bio-compatible, and biodegradable nature.

In terms of biomaterials, pectin can have different applications, including food packaging, pharmaceuticals, nutraceuticals, drug delivery, tissue engineering, and cosmetics.

The properties of pectin can be improved and modified

with bio-fillers or in a mixture of other gelling ingredients (polymers). For example, adding a bio-filter like peels can help keep your bioplastic shape and reduce shrinkage.

Petri dish: A petri dish is a small plastic container. It is usually used to culture (grow) microorganisms in a controlled environment but can also be used as molds for material science experiments like you just did. Petri dishes come in several sizes, including 6 cm and 10 cm. They are sometimes called “plates.”

Polymers: Plastics are chains of repeating molecules linked together called polymers. Whether natural or artificial, polymers are long molecules made by linking up smaller repeating molecules. Wool, cotton, and silk are natural polymer-based materials. Cellulose, the main component of wood and paper, is also a natural polymer, as are the starch molecules made by plants. Learn more about polymers here: <https://www.sciencenewsforstudents.org/article/explainer-what-are-polymers>

Shrinking: See drying.

Starch: is a white flour-like powder typically obtained from corn or potatoes. Starch itself is a polymer made by plants to store energy. It can be used as the polymer in your mixture or an additive to another polymer mix.

Troubleshooting

Here are some possible common issues:

My bioplastic does not solidify/gel.

When done correctly, the bioplastic will harden into a sheet. If it is not:

1. You likely did not heat (boil) the water before or after adding the ingredients
2. You might not have added all the powder from the tube, resulting in too much water vs. ingredient(s).
3. You may not have fully dissolved the powder, meaning it cannot turn into a gel and will look cloudy. You can practice by making Jell-O! Next time heat and swirl longer to ensure the powder is fully dissolved.

My bioplastic breaks:

Don't worry; some of the bioplastics recipes give thin, brittle plastic sheets. If your sheet or sample breaks, you can:

1. Melt it back down! Go back to the recipe and add the same amount of water to your mixing bowl! Add your broken plastic sheet and microwave until boiling. Stir and pour into an oiled mold. Note that bioplastics are hard to melt back down. Try the method below to repair them instead. Note that trying to melt the biocomposites might not work depending on the filler you used.
2. You can repair most bioplastics by dipping or coating the two edges of the break with boiled water and then pressing the edges together again. Leave to dry.

If anything else causes you issues, please contact us : help@amino.bio

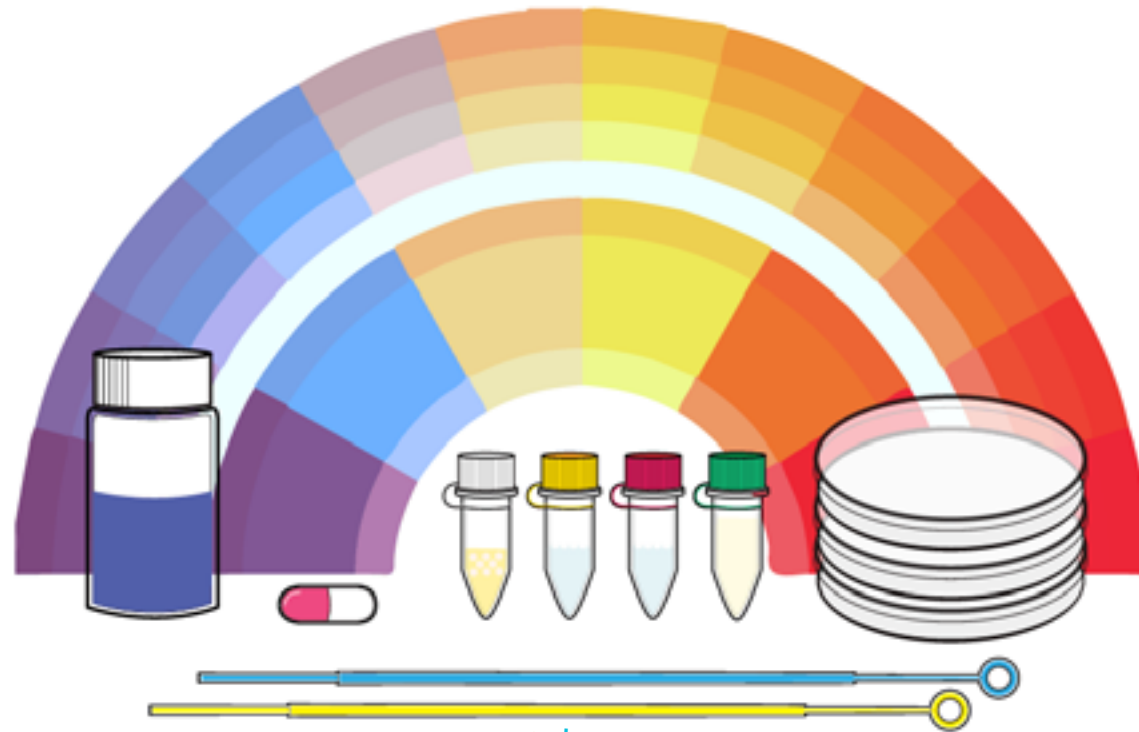
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