MAKE WITH BIOLOGY
amino labs

BIOPLASTICS KIT BETA

ANALYSIS MANUAL

www.amino.bio

Version 3.0, January 2023

BIOPLASTICS KIT™
ANALYSIS MANUAL

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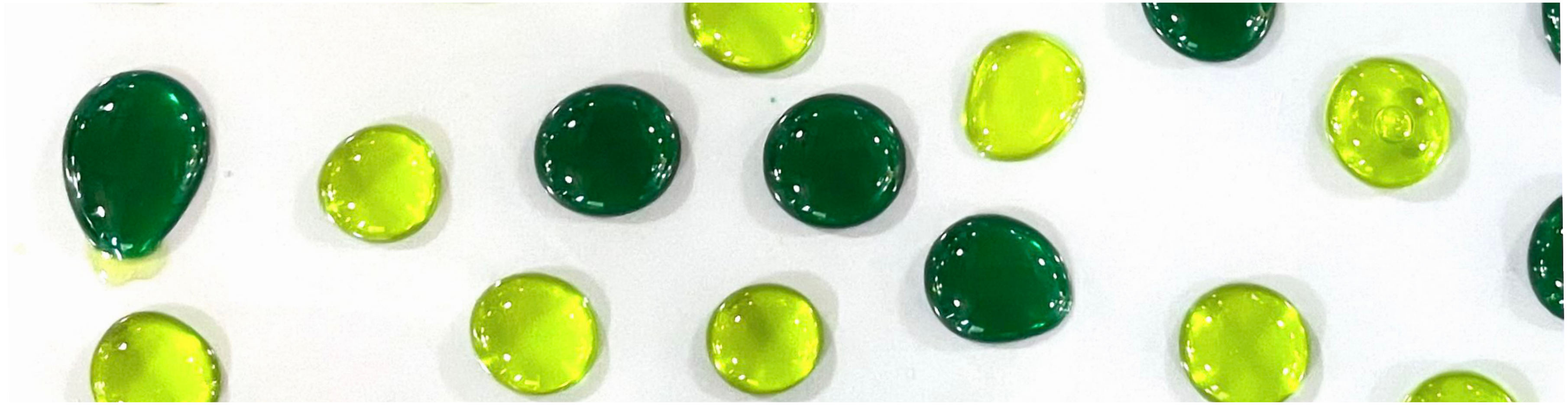
Welcome! Let's get started



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 and get the most out of your kit.

This manual will show you how to analyze the Bioplastics you have made using the Bioplastics Kit and the Bioplastics Making instruction manual. This manual is only meant for analysis after you have made and dried your bioplastics according to the other manual. Complete this step first! As in the other manual, the analysis activities will be broken up in a few different days. Feel free to complete them all in one go if you wish! As long as the materials are dry, you are ready.

Don't forget, the final section of the manual is there to help you -- a glossary, troubleshooting, and our contact information.

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 manipulating your experiment, or the hardware.
- 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 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

The Bioplastics Kit™: Material Analysis

The Bioplastics kit enabled you to combine different biological-based ingredients to create a range of bioplastic with different properties, from bio-foams to rubbery strings! In this second part of the experiment, you will be able to explore some of the basics of material analysis by re-visiting your material library and running tests on them.

What is a material library?
You may have noticed that we have called some of your bioplastics “samples” or “material sample” in the last part of the experiment. In general, a sample is a small quantity of something like a material, that is intended to show what a larger amount of that same thing is like.

For example, when you taste some of the cake batter you are making, you are tasting a sample of cake batter to get an idea of what the entire cake will taste like. It would not make sense to eat the whole cake batter just to get an idea of the properties of the cake batter. In the same way, a material sample of bioplastic is a small piece of bioplastics that you can use to understand how making a larger quantity of the material would behave. This way, you can find out what recipe of bioplastic to use if you want to make a shopping bag, a rubber ball or fork.

Following this idea then, a material library is a resource for material research, exploration, and experimentation that is made up of an expanding collection of material samples, analysis, and notes. All the bioplastics you have now, and may continue to make in the future, can be part of your biomaterials library!

Getting started
By following the instructions on the next pages, you learn how to analyze these different materials to learn more about what effect the ingredients and techniques you use have.

These analysis can be done individually (although you might want to have an extra pair of hands nearby if you can!), in small groups or in the classroom. If you are in the classroom and completed many samples, take advantage of all the data you’ll collect to share and compare all your results!

Items you will need

- Computer with a browser to complete worksheets online or a printer, pen and paper.
- Elevated surface to set on your work area like a shoe box or pile of books, ~ 6 inches high
- Tape like masking tape, adhesive tape to old your samples in place
- Smart phone with a front camera
- Flashlight, or an additional phone with a flashlight function
- You will need the following bioplastics:
  - All five of your Day 1 bioplastics,
  - The blue dye Day 2 bioplastics and bio-foams,
  - The dumbbells of Day 3,
  - The bio-composites of Day 4.
  - If you'd like to run some of the analysis test on other samples, that's great too!

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

Timeline

The Bioplastics Kit™ analysis activities are organized around the first four "Days" of bioplastics you made. These analysis can all be done on the same day, as soon as all the bioplastics are dry, or broken down into four sessions. Each activities takes between 20 and 50 minutes.

You can also try a final activity in which you try to degrade the bioplastics you created in the soil and/or in water. While the active time for this experiment is short, 15-20 minutes to set up the experiment, and ~5 minutes to take your measurements, the degradation of the plastics can take quite a long time, stretching into months. If you have the time, it can be a fun experiment to try.

1: Material Properties table (Day 1 Gelatin bioplastic)
Day 1, ~30 minutes

2: Transparency test (Day 2 Bio-foams, dyed plastics)
Day 2, ~40 minutes

3: Tensile strength test - advanced (Day 3 Starch bioplastic)
Day 3, ~30 minutes

3: Walk the plank test - simple (Day 3 Starch bioplastic)
Day 3, ~30 minutes

Biodegradability tests in water and soil (any bioplastic)
Day 4 + ~ 30 minutes

Experiment Protocol

Prepare your space

Goal Set yourself up for success.

Materials not in your kit
Spray cleaner
Paper towels
Optional: Pair of gloves

Make sure you have the necessary materials as explained on page 6 and that you have read and understood the safety guidelines.

1. If you have them, put on your gloves, and if you have one, your lab coat or apron.
2. Remember that you can dispose of used items in the garbage. Do 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 and air cannot go into them). Wipe down your work surface with the cleaner before starting
4. Make sure your bioplastics are fully dry before your start your analysis!

Day 1: Material Properties table

1. Analyze your gelatin/glycerol bioplastics

Goal **Test your bioplastics to discover how the different ingredients change their properties.**

Materials from your kit
- Control bioplastic,
- Decreased gelatin bioplastic,
- Decreased glycerol bioplastic,
- Increased gelatin bioplastic,
- Increased glycerol bioplastic

Materials you provide
Pen/paper/printer or access to google sheets
Dish or hand soap

Today, you will analyze the material properties of your first five bioplastic samples from Day 1. These used gelatin and glycerol as their main component and each sample had a different proportion of these ingredients. Because of this, you will be able to attribute specific characteristics to the ingredients.

Prepare your samples for analysis

Remove the bioplastics from their mold

1.1. You should only remove your gelatin bioplastics from the mold once they are dry (no longer gel-like to the touch). Are they dry to the touch? If they are, great! Continue. If not, wait another 24 hours or more.

1.2. With gloved hands, grab a corner of each bioplastic and peel it up slowly and gently. If the bioplastic is hard to grab, run a toothpick or your gloved fingers between the edge of the bioplastic and the mold.

Degrease the bioplastics

1.3. If your bioplastics feel oily after removing them from the mold, you can degrease (remove the oil) them easily. Add a few drop of dish soap to the oily side of the bioplastic and rub to dissolve the oil. Rinse the soap off in COLD water as quickly as you can. Since your bioplastics are water-soluble (can be dissolved in water) be quick when rinsing them. **Do not use hot water as this will melt them!**

1.4. After degreasing, the bioplastics may be a bit tacky. Let them dry for a few minutes on a solid surface.

Learn from your experiment

What differences are there between your plastics?

1.5. Use the *Material Properties table* on the next page to evaluate each of your samples. You can print it out five times - one for each sample - or fill out an online google document here: www.amino.bio/bioplastics-analysis

1.6. Based on your material evaluation, can you identify which properties relate to each ingredient? Fill out your observations in the second table, *Ingredient Properties table*, by printing the page or in the google document at the link above. After you are done, you can learn more about the properties of each ingredients by going to the glossary at the end of this manual. Did you find similar properties in your evaluation?

1.7. Once you have observed and handled your bioplastics, you can put them back in their molds. They are now part of your material sample library. You may choose to use them again later on, or you can dispose of them at the end. You can also wash, rinse and dry your mold and keep it to re-use in the future.

Material Properties Table: How would you describe your material?

Material sample:______________________________

Property	Evaluate your material on a scale from the property on the left to the property on the right. Draw an X in the box that is most appropriate for your sample					Property
Brittle	Does the sample crack when you fold it? If it breaks or cracks, it is brittle. If it does not, it is flexible					**Flexible**
	Breaks	cracks		some flex	fully flexible	
Smooth	How does the sample feel when you pass your hand over it? If your hand glides without catching on the surface, it is smooth. If you feel bumps/imperfection on the surface, it is rough.					**Rough**
	very smooth	mostly smooth		mostly rough	very rough	
Glossy	Is there any reflection of light on the bioplastic? If there is a shiny reflection on your plastic, it is glossy. If your plastic does not reflect any light, it is matte.					**Matte**
	very glossy	mostly glossy		mostly matte	very matte	
Light	Is there a weight difference between your bioplastics? Use your scale to measure the control. If the other samples weigh more than the control, they are heavy. If they weigh less, they are light.					**Heavy**
	much lighter	lighter	same as ctrl	heavier	much heavier	
Non-elastic	Hold each end of your bioplastic and try to pull it apart. If it stretches, it is elastic; however, if it rips and does not stretch, it is non-elastic.					**Elastic**
	rips immediately	rips after a light pull	rips after a medium pull	rips after a long pull	does not rip	
Opaque	Can you see light through the sample? If you can see through the sample, the material is transparent. If you cannot see light, it is opaque.					**Transparent**
	No light	very little light	translucent	some light	Clear	
Heat resistant	For this last test, microwave your sample for 5 seconds in a bowl or on a plate. If it does not melt, it is heat resistant. If it melts, it is susceptible to heat.					**Heat susceptible**
	No change	barely sticky	sticky	somewhat melted	fully melted	

Ingredients Properties Table

Reflect on the properties you analyzed in the previous table. Based on your material evaluation, can you identify which properties relate to gelatin and which relate to glycerol? Did having more or less water change anything? Fill out your observations

Ingredient	**Concentration** (None, high or low)	**Properties it affects/creates**

Day 2: Transparency test

2. Analyze your bio-foams, dyed and textured samples

Goal **Test the transparency of your transformed bioplastics.**

Materials from your kit
Blue dyed plastics
Bio-foams
Blown texture sample

Materials you provide
Pen/paper/printer or google sheets
Dish or hand soap
Phone with a front camera
Tape
Flashlight (or a second phone to use as a flashlight)
Box/books to create a ~6" raised surface on your work table

Today, you will analyze the transparency property of your dyed bioplastics. You will remember adding different quantities of dye drops to four of your samples? You'll use these and your mobile phone to better understand how different level of dye in bioplastics affects the amount of light that can pass through. You will also test your bio-foams and blown texture bioplastic to see how those affected the light's ability to pass through the sample.

Prepare your samples for analysis

2.1. Only remove your bioplastics from the mold once they are dry (no longer gel-like to the touch). Are they dry to the touch? If they are, great, you can continue. If not, wait another 24 hours or more.

2.2. With gloved hands, grab a corner of each bioplastic and peel it up slowly and gently. If the bioplastic is hard to grab, run a toothpick or your gloved fingers between the edge of the bioplastic and the mold.

2.3. If your bioplastics are oily, get a few drop of dish soap on the oily side of the bioplastic and rub it around to dissolve the oil for a few minutes. Rinse in COLD water as quickly as you can. After degreasing, the bioplastics may be a bit tacky/gummy. Let them dry a few minutes on a solid surface.

Learn from your experiment

What is light translucence and how is it measured?

You will remember that translucent materials fall between transparent (clear) materials on one end of the spectrum and opaque materials on the other. If some light can be seen through a material, it is a translucent material. It is the level of light passing through the material that is measured to inform us about the material's translucency.

Scientifically, translucency describes the scattering of light as it passes through an object. The more light passes through, the more translucent the material is, and this amount of light passing through is measured in the unit Lux (lx). You may be familiar with lumens when talking about light. Lumens measure the total amount of light emitted by a light source, while the lux measures how much light falls on a certain area. Specifically, one lux is equal to one lumen illuminating one square meter. Lux are measured using a device called a Lux meter. To measure the light passing through the material, the Lux meter contains a light sensor and a screen to display the values in lux (lx). Since the front camera of smartphones can detect changes in light, they be used as Lux meters.

Today, you will use your smart phone's front camera to measure the light that passes through your sample and ontain their translucency value in lux units. You will begin by measuring the intensity of a light source with your Lux meter when it is unobstructed. This value will be your reference point and will represent the maximum amount of light which can hit the lux meter's detector. Then, when you will place your dyed bioplastics over the lux meter's detector, the dye molecules in the plastic will absorb some of the light and cause less light to reach the detector. For the textured bioplastics (baking soda, bubbled and foamed bioplastics), the shape of the bioplastic will cause the light to scatter which will change the intensity of light which passes through. Since the recipes included different amounts of dye, some of your bioplastics will scatter more light than others. Can you guess which bioplastic will allow the most light to pass through?

Setup the LUX Meter

2.4. Download the free app "Light meter LM-3000" for IOS devices or "Sensor Sense" for android.

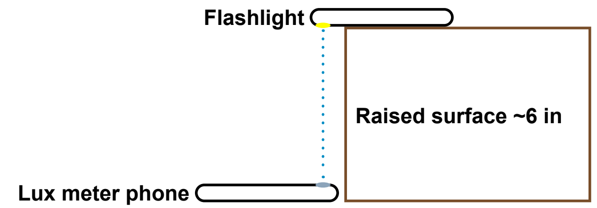
2.5. Take a piece of tape and place it over the screen-side/selfie camera of your detector phone. This tape will act as an optical diffuser for the light coming into the sensor on your phone's camera. Congratulations! Your phone has now become a LUX meter.

2.6. Open the LUX meter app and place your LUX meter phone with the screen-side is facing up.

Setup the Light Source

2.7. Take your box, pile of books, or other items you are using to create your raised surface. Move it close to the phone's front/selfie camera. If you want, you can tape down your phone in place to prevent it from moving as you take your measurements.

2.8. Take your flashlight (or borrow a second phone with a flashlight) and place it on top of your raised surface with the flashlight pointed down, towards the Lux meter phone. The light coming from the flashlight should point directly into the camera of the Lux meter phone. Make sure it won't move as you take your readings.



Data Collection

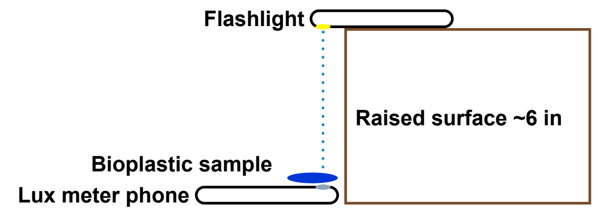
2.9. Print, or visit your google document you copied fromwww.amino.bio/bioplastics-analysis to find the table below. You will use it to gather your Lux meter data.

2.10. In the LUX meter table, record the initial LUX displayed on the screen in the reference column. Remember, the value on the lux meter without anything in between it and the flashlight is your reference reading.

2.11. Place your first bioplastic over the detector phone's camera. You can set it down on the camera itself.

2.12. Record the LUX value displayed on the LUX meter table for the appropriate bioplastic.

2.13. Repeat for all the bioplastics. What can you learn from the Lux readings?



2.14. Once you have completed your readings put them back in their identified containers. They are now part of your material sample library. You can use them again later on or dispose of them at the end. You can wash your molds and keep them to re-use.

Lux Values of Day 2 Bioplastics Table

Material	Reference	1 drop blue	5 drops blue	10 drops blue	15 drops blue	Soap bio-foam	Baking soda bio-foam	Blown texture
Lux								

Day 3: Tensile strength test

3. Analyze the stress and strain your starch bioplastics can withstand (advanced experiment)

Goal **Test the tensile strength properties of your starch bioplastics.**

Materials from your kit
Day 3 dumbell shaped bioplastics

Materials you provide
Dish or hand soap
Newton Scale (N) or spring weight scale (Kg)
Computer
Two tables or desks
Sharpie-type marker
~6” long rod like a wooden dowel, metal from a coat hanger,
Tape - to hold the ruler and rod in place
Video recorder - your phone for example
Tripod or stand for your video recorder/phone or a chair

Today, you will use a spring scale and video analysis to analyse the tensile strength of starch bioplastic. If you do not have the materials for this, don’t worry! You can watch videos of the analysis to learn the process and results (https://youtu.be/OxG3fMnq72M), and do a different analysis activity by skipping to Day 3: Building a structure.

Prepare your samples

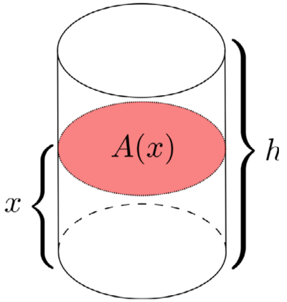
3.1. Are the Day 3 dumbell-shaped bioplastics dry to the touch? If they are, great! Continue. If not, wait another 24 hours or more.

3.2. Grab a corner of each bioplastic and peel it up slowly and gently. If the bioplastic is hard to grab, run a toothpick or finger between the bioplastic and the mold.

3.3. Get a few drop of dish soap on the oily side of the bioplastic and rub it around to dissolve the oil for a few minutes. Rinse the soap off in COLD water as quickly as you can. Let dry a few minutes if nedded.

Learn from your experiment

What is tensile strength?



To understand the behavior of our bioplastics under tension, we will perform tensile testing to determine how much strain and stress it can withstand. Stress refers to the force ‘flowing’ through a material. If you were to ask an object, such as a pillar, how it’s feeling carrying a load, it would tell you all about the stress it’s under. This is measured by dividing force over cross sectional area using units N/m2 or Pascals (Pa). A thicker material can carry more load than a thinner one because it has a larger cross-sectional area. However, the stress that both experience when they finally break is the same.

Strain, on the other hand, refers to the elongation experienced by a material. Everything is at least a little bit elastic, and will deform when a force is applied. Because strain states how much a material has deflected over a certain length, it has no units due length being on both sides of the fraction. A strain value of 1 means the material has experienced no deflection. A value of 2 means the current form of the material is two times longer than the original.

When a force is applied to an object, it will experience stress and strain. As you increase the force, the stress will increase too. Similarly, the object will begin to elongate, so strain will also increase with force. Each material has a different stress-strain relationship; a steel rod behaves very differently from an elastic band. By understanding the relationship between stress and strain, marvels of engineering can be accomplished.

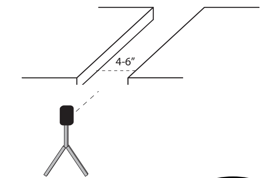
In this experiment, you will test the relationship between stress and strain of your three dumbbell shaped bioplastics from Day 3. Each bioplastic was made from different ratios of gelatin and glycerol, which will create different material properties. After performing tension tests, you will record the data you collected on a spreadsheet then graph it to compare and visualize the different material properties related to stress and strain between the three bioplastic samples.

Measuring tensile strength

To complete this analysis, you can watch a 3-part video for a work-as-you-go guide or read through the instructions below. You can find the videos here:

Part 1: https://youtu.be/OxG3fMnq72M Part 2: https://youtu.be/kPFJinVMI7I Part 3: https://youtu.be/Ch9dSJF3aMI

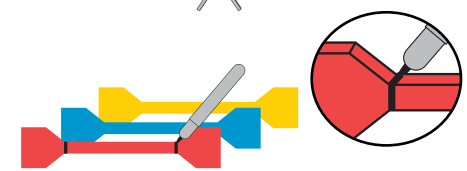
Set up your space



3.1. Move two tables or desks besides each other so that there is a ~ 4 inch gap between them.

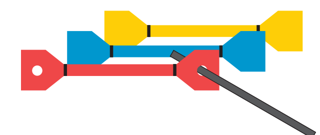
3.2. Place your tripod or phone stand, if you have one, in front of the tables so that the camera will be in line with the surface of the tables, and lock in your camera or phone. If you don't have a tripod or stand, you can find a chair you will be able to rest your arms on while you film to prevent any camera movement.

Prepare the bioplastics for testing



3.3. Take a black marker (like a sharpie) and draw a line around both ends of your bioplastic's thin section, just before it widens out into the ▷ ◁ ends. Make sure to draw the line all round the bioplastic.

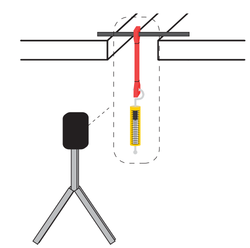
3.4. With a metal rod or dowel, poke holes through both ▷ ◁ ends of all three dumbbell bioplastics.



3.5. You will start by testing the red control dumbell. Using the hole you created, suspend your bioplastic between the two tables and tape the ends of the rod to the tables to prevent it from moving.

3.6. Insert the hook of the newton meter or weight scale through the hole on the bottom end of the hanging bioplastic. Make sure that the numbers on the scale you use are facing towards the camera.

Record video

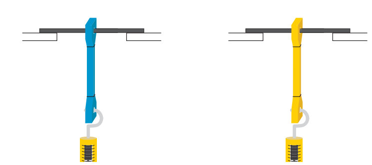


3.7. Set the video quality on your device to the highest resolution possible at the lowest frame rate, for example 4k at 30 fps.

3.8. Begin recording, making sure that you can see the entire dumbell and scale in the video, and that you can read the numbers on the scale. Your camera should not move while you record.

3.9. Slowly pull the scale straight down until the dumbell breaks. Try to pull the scale at a slow and controlled rate and be consistent with each bioplastic. Stop the recording once the bioplastic breaks.

Clean up and reset for your next bioplastics



3.10. Peel off the tape that is securing the rod and remove the bioplastic that remains on it.

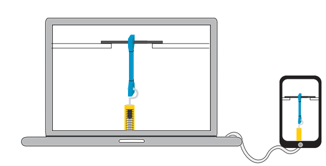
3.11. Repeat the setup and recording with the other two bioplastic dumbells.

Upload your results and get your video ready

3.12. Upload your videos from your camera to a computer that has internet access.

3.13. Click on https://pjl.ucalgary.ca/studentResources/videoAnalysis/pjlVideoAnalysis.html and select "Open video".

3.14. A window will pop up. Go to the media tab and select the video with the red control bioplastic.



3.15. Start playing the video in the browser. Watch it all the way through to take note of the time where you begin pulling the scale and the time when the bioplastic breaks.

3.16. Restart the video and skip ahead to the moment when you begin pulling and pause the video at the point just before you begin to pull on the newton meter or your weight scale. At this point, the newton meter will have a force of about 1 because of the force of gravity pulling down on the meter.

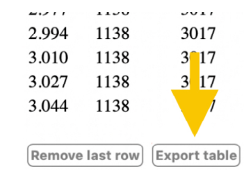
Gather the data from the video for **strain analysis**

3.17. Hover your mouse over one of the corners of the black line on the bioplastic, then click the mouse. You should see the video move ahead one frame as you do this. Each time you click, the time and coordinates (X & Y) are recorded on a table below the video and the frame moves ahead by one.

Pro tip: Make every effort to click on the same corner each time to be consistent with the object you are measuring.

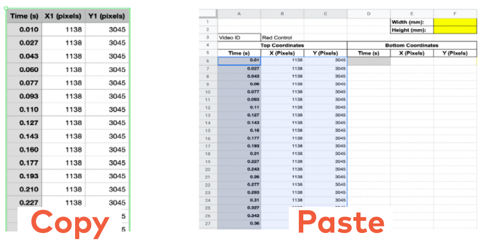
3.18. Continue to click on the black line on your bioplastic, in the same corner as before. You will need to move your mouse each frame to click on the same spot as the black line will move as the bioplastic is pulled.

3.19. Do this until the bioplastic breaks, which can take about 5 minutes of clicking. When this happens, scroll to the bottom of the X & Y data then select "export table" and download the data to your computer.



3.20. Click to make a copy of this google document for your analysis: https://docs.google.com/spreadsheets/d/15WV2nNizGt1zMl_JAEP8V2K5P1kXuaUvOjEyV_lwAAI/copy?usp=sharing

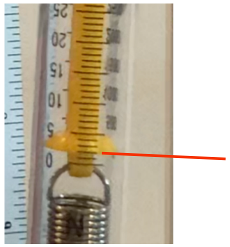
3.21. Open your downloaded file from your video analysis, select all the data and copy and paste it into your google spreadsheet in the control bioplastic tab, in the first three columns under *Top Coordinates*: "*Time (s)*", " *X (pixels)*", "*Y (pixels)*".



3.22. After entering the data in your spreadsheet, return to the video and refresh the page to reset the table.

3.23. You will now repeat the same process of data collection, this time for the bottom line you marked on the bioplastic sample. You will paste this data in the next three columns under *Bottom Coordinates:* "*Time (s)*", " *X (pixels)*", "*Y (pixels)*", making sure that your "Time (s)" column match up. Important: All your data must begin and end with the same time points as in the previous data collection. To do this, ensure that the first time point you record for the top coordinates and bottom coordinates are the same. Look at the "*Time (s)*" column in your google sheet to see the time you started at.

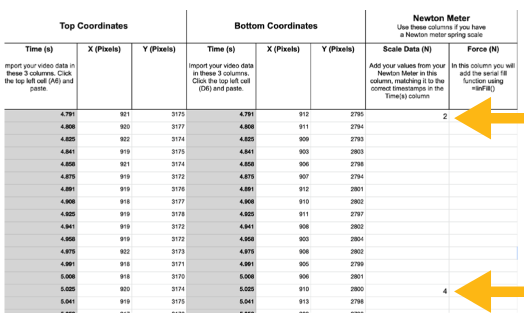
Note: If you navigated away from the video app, you may need to upload the video again.



Gather the data from the video for **stess analysis**

3.24. You will know record the data from your scale, as seen on the video. Restart the video for the red bioplastic and skip ahead to the same timestamp that you began logging your data earlier.Once again, all your data must begin and end with the same time points as in the previous data collection. For example, the first time points for the top coordinates, bottom coordinates and the Newton or Weight Meter must be the same.

3.25. Look at your scale in the video and record the initial reading in the *"Scale Data (N)"* column under Newton meter if you have a Newton meter or in the *"Scale Data (Kg)"* column if you are using a spring weight scale.



Note: If you are using the spring weight scale, the google spreadsheet will automatically convert any data you enter in "*Scale Data (Kg)*" to its corresponding Newton force in the "*Converted Data (N)*" column.

3.26. Scroll through the video until you see the *"Scale Data"* values you need to record on your scale. For the red bioplastic, you will record *Scale Data* for every 2 units after the initial measurement. For example, if your first measurement was 2, the next *Scale Data* value you will record is 4, then 6, 8, 10, 12, etc., until the bioplastic breaks.

3.27. Once you find your next *Scale Data* value in the video, make note of the timestamp. Then, go to your spreadsheet and find this timestamp in the *"Time"* columns.

3.28. Add the value from your scale in the *"Scale Data (N)"* or *"Scale Data (Kg)"* cell corresponding to that timestamp. Repeat for all the values you have to record.

Note: for now, you will be leaving blank cells between your values. That's ok, you'll fill them in next

Use the serial filling function to complete your data set.

Now that you have recorded all your values from the video, you will fill in the blank cells in your *"Scale Data (N)"* or "*Converted Data (N)*" column using a spreadsheet function called the serial filling function.

3.29. Select the cell in the *"Force (N)"* column next to your first value from the *"Scale Data (N)"* or *"Converted Data (N)"* column. In this cell, type "=linFill("

Newton Meter	
Data	Force (N)
2	=linFill(G6:G13
4	

3.30. Then, select all the cells in the appropriate *"Data (N)"* column between your first scale value and the next one, including your two scale values. For example, you will have selected the cells in the data column from 2 to 4 and all the empty cells in between. You can do this by clicking your first cell and dragging down the selection box to your next value.

3.31. After selecting the cells, type ")" or press enter to close the brackets on the function. The cell should look something like "=linFill(G6:G20)".

Newton Meter	
Data	Force (N)
2	2
	2.285714286
	2.571428571
	2.857142857
	3.142857143
	3.428571429
	3.714285714
4	

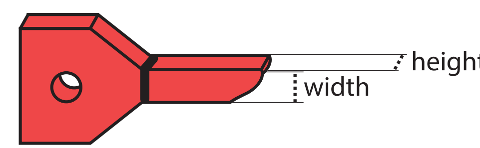
3.32. Press enter on your keyboard and watch as the cells in the *"Force (N)"* column between the two data points you entered fill in. You'll notice the cell in the same line as your last value did not fill in. That's normal. This cell will be your starting point for the next function.

3.33. Repeat this process until you have filled out the entire column. For the last cell in your *"Force (N)"* column, simply copy over the value from the *"Data (N)"* to the *"Force (N)"* column.

Note: If you need help filling out your data, you can watch the follow-along video part 2: https://youtu.be/kPFJinVMI7I

Measure your cross sectional area

3.34. Using a ruler, measure the width and height of the thin part of the broken bioplastics.



3.35. Record the values in mm at the top of each bioplastic spreadsheet to enable the built-in functions to calculate distance, strain and stress.

Repeat for the other two bioplastics

3.36. Repeat gathering the data from video and inputting it in the google sheet for both the blue high glycerol and the yellow high gelatin bioplastic. When it is time for you to record the scale data from the blue glycerol bioplastic, you will want to record every unit after the initial measurement (ex: 1, 2, 3, 4, 5...)

When its time for the yellow gelatin bioplastic, you will want to record the initial unit then every 5 units (ex: 1, 6, 11, 16...)

Analyse your data

3.37. Watch the youtube video part 3 to learn how to analyze your data and generate a graph: https://youtu.be/Ch9dSJF3aMI

3.38. Then, look at the auto-generated graph in the spreadsheet. Which bioplastic withstood the most stress? Which bioplastic underwent the highest strain and stretched the most?

Where did the control bioplastic fall in comparaison to the other two? Does this make sense if you consider the proportions of ingredients for each sample?

Day 3: Walk the plank test

4. Use your starch bioplastics to see if you can build a self-supporting structure (simple experiment)

Goal **Test the properties of your starch bioplastics by seeing if you can build a structure that is self-supporting.**

Materials from your kit
Bioplastics from day 3

Materials you provide
Pen/paper/printer or google sheets
Dish or hand soap
Tape

Today, you will use the material properties of your starch bioplastics to build a structure that can support itself. Since each of these had different proportions of ingredients, you will want to pay attention to their materials properties as you plan and build a plank that holds itself up from the edge of a table. Are you working against some classmates? Let's see who can use the materials in the best way to build the longest plank!

Do you remember what properties high glycerol and high gelatin create? You can go back to your Day 1 bioplastic analysis if needed.

Prepare your samples

4.1. Are the starch bioplastics strings and dumbells dry to the touch? If they are, great! Continue. If not, wait another 24 hours or more.

4.2. If the bioplastics are oily, get a few drop of dish soap on the oily side of the bioplastic and rub it around to dissolve the oil for a few minutes. Rinse the soap off in COLD water as quickly as you can. Let dry a few minutes if nedded

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Learn from your experiment

Using your new knowledge of material properties, you will now build a plank made out of your bioplastics. The plank needs to extends from a table or desk edge into the empty air and support itself to create the longest possible surface without falling or touching the floor.

4.3. What differences are there between your extruded rubbery strings? Identify which are strong and solid, and which are more flexible and lightweight. You can sort them on your worktable by properties.

4.4. Prototype your plank; use tape, or knots to attach your bioplastics together into your first test plank

4.5. Hold one end of your plank on the edge of the table and suspend the rest over the empty air. Does it support itself? Measure the lenght of your plank. If you are working with other teams, who has the longest plank?

4.6. Pay attention to what works and what doesn't on your prototype (and others). Repeat the prototyping stage to see if you can create a longer plank. Can you create a plank that also holds the weight of an object placed on it?

4.7. Once you have built a few planks with your bioplastics, analyze which bioplastic ingredients gave which properties in the table below.

Ingredients and Methods Properties Table

Based on your builds, can you identify which properties relate to which ingredient or extrusion method? Add notes below.

Sample	Properties created/affected
Control bioplastic	
Increased gelatin bioplastic	Extruded without wait time
	Extruded with wait time
Increased glycerol bioplastic	Extruded without wait time
	Extruded with wait time

Day 5: 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 the 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 left. But 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?

5. 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

Because our bioplastics are water-soluble, you know that most of them, save for the bio-composite, would dissolve in hot water. However, when plastics ends up in the ocean or other water bodies, the water is much cooler than that. The test here will be to see if your bioplastics would dissolve in room temperature water.

5.1. Add 400 mL of distilled or tap water in your beaker.

5.2. Choose one or more of your bioplastic sample you want to test for hydro-degradation. We recommend half the bioplastics of Day 1, the star of Day 2 or one of your Day 4 bio-composites.

5.3. 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.

5.4. Add your sample to the water. Your experiment is underway!

5.5. 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.

5.6. Once your water looks clear, take your last measurement and notes (you can mark the weigh as 0 if there is no sample left).

5.7. 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.

Are bioplastics biodegradable?

6. 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.

6.1. Choose the bioplastic sample(s) you want to test for biodegradability. We recommend the half bioplastics of Day 1, the dumbells of Day 3 or the bio-composites.

6.2. Weigh the sample as it is now. Note the measurement in the table below, alongside the time and day you start your degradation experiment.

6.3. 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.

6.4. 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!

6.5. 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.

6.6. 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!

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 sample library:** If you want to preserve them, you can place your samples with their identifying labels in a container. Or, you can attach them in a binder along with any experiment notes and material property analysis so that you can reference them in the future.

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, at this point, the bioplastics you've made cannot go into the traditional recycling stream as the recycling industry is not ready to deal with these bioplastics.

C. **Disposing of your other kit material:** All tubes, bottles and plastic packaging can be disposed of in a recycling bin or garbage. Of course, they can also be washed and kept for reuse along the molds, silicone tray, paintbrush, syringes, etc. 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.

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.

Cornstarch: see starch

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 what it could 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, pharmaceutics, 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

More Information

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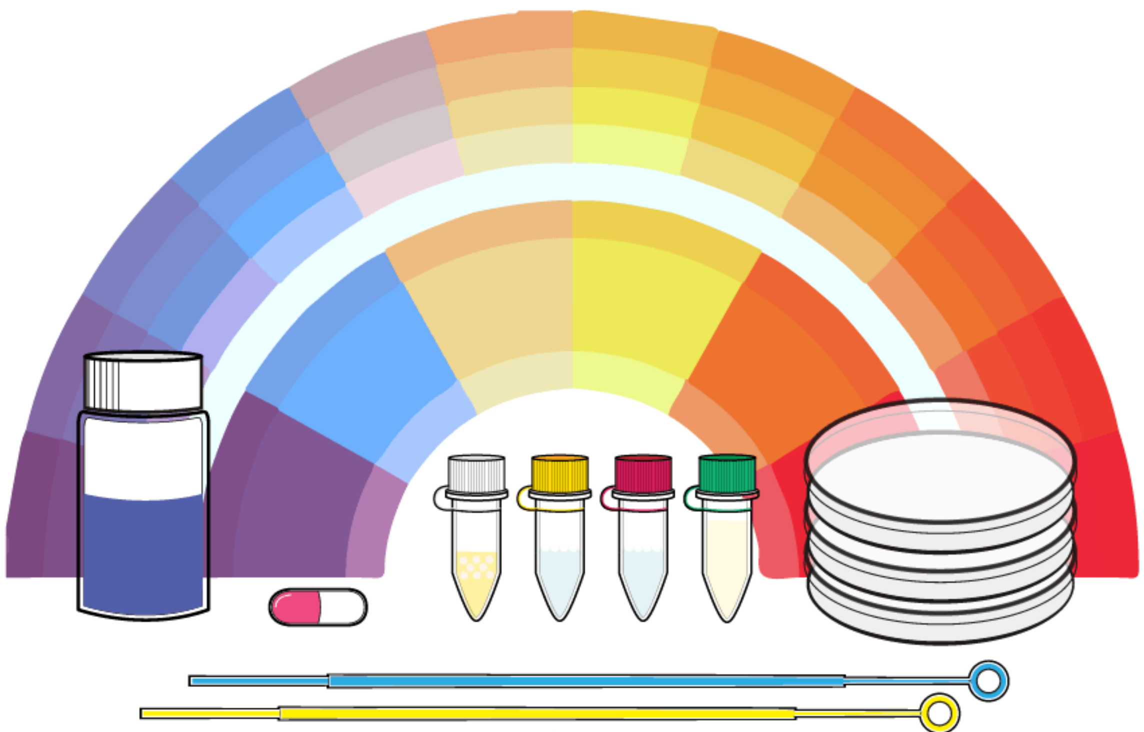

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