MAKING STUFF WITH DAVID POGUE

DEMONSTRATION

Instant Cheese Bioplastic

NOVA PBS

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MAKING STUFF CLEANER Demonstration

Overview

TITLE
Instant Cheese Bioplastic

SHOW
Making Stuff: Cleaner

DESCRIPTION
In this two-part demonstration, visitors will learn about **bioplastic** and see a simple bioplastic made by curdling milk with vinegar in a process similar to cheese making.

OBJECTIVE
Visitors will learn about bioplastic, a material made of plant or animal matter that is cleaner because it breaks down more easily in the environment than petroleum-based synthetic plastics.

OTHER KEY TALKING POINTS
Materials scientists are developing new cleaner materials that are safer for the environment.

AUDIENCE
General public, ages 10 and up

TIME
Set-up: 10 minutes
Presentation: 20 minutes

Each year, we extract some 30 trillion tons of raw materials from the Earth. We turn iron ore into steel cars, petroleum products into plastics, and metals into batteries. What happens to all those raw materials when the useful life of our stuff ends? Many end up in landfills or at the bottom of rivers, lakes, and oceans.

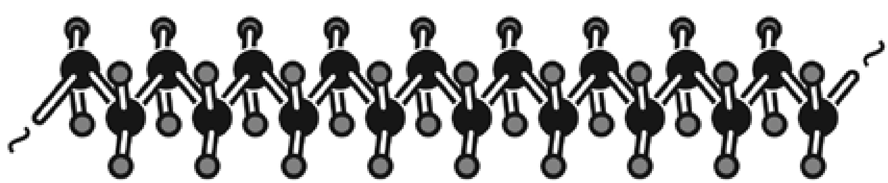
NOVA's *Making Stuff: Cleaner* explores the rapidly developing science and business of clean energy and clean materials. The show follows innovative materials scientists as they work to invent cleaner materials to help solve environmental problems created by the production and use of automobiles, plastics, and batteries. These new materials—including plastics made from sugar instead of petroleum and tires made from orange peel oil—could provide the energy and materials we need without polluting the Earth.

Materials scientists are asking:

- What if we lived in a zero-waste world where every product could be recycled, reused, or composted?
- How can we replace dirty materials with cleaner biomaterials?

Science Background

The word ***plastic*** has many meanings. In everyday language, it means a material or object that can be molded or shaped. Such materials have the property of **plasticity**. Scientifically, however, a plastic is a type of **polymer**, a substance made of long chains of molecules. The properties of a plastic—whether it bends or stretches, remains soft or hardens into a solid—depend on how those long chains are arranged.



Molecular Structure of a Polymer
Polyethylene (PE), the most widely-used plastic, is made of long chains of carbon and hydrogen atoms. Polyethylene bags and bottles, which are not biodegradable, often end up in landfills and the ocean. Materials scientists are working to develop polyethylene made from sugars and grain, which are biodegradable and cleaner for the environment.

Polymers, including plastics, can be synthetic or natural. Today most plastics are synthetic and made from petroleum. It can take hundreds of years or more for light, heat, or moisture to break them down in the environment. When they do degrade, some can leach harmful substances into the water or soil. However, bioplastics are usually **biodegradable**, which means they will decay as microbes eat them.

This presents a challenge to materials scientists who must design materials that are strong and durable enough to be useful—but not so strong and durable that they remain in the environment long after they are no longer needed.

One type of bioplastic is made from the protein found in milk, called casein (pronunciation: \ˈkā-ˌsēn, "*kay-seen*"). Casein plastic, invented in 1899, is made by a process similar to cheese making in which an acid (in this case, vinegar) is added to milk. This causes the casein proteins to unfold and reorganize into long chains of molecules forming a polymer. This process is called **polymerization**.

In the early 20th century, before petroleum-based plastics became widespread and relatively inexpensive to produce, casein plastic was used to make jewelry, buttons, door handles, and acrylic paints. Today it is a component of some glues. Another, harder form of casein plastic, called *galalith*, which means "milkstone" in Greek, is produced by adding formaldehyde, which is a toxic chemical.

Q Can petroleum-based plastics be made biodegradable?

A Yes. So-called "superbugs" are microbes developed specifically to break down petroleum or petroleum products in a process called *bioremediation*—but it's not common, cheap, or easy.

Q What are some other uses of casein?

A Casein is also made into white glue—just add extra vinegar (about 1/3 cup to 1 cup of milk) and a teaspoon of baking soda. Though Elmer's® glue features a cow on the bottle and belongs to a dairy company (Borden®), it's no longer a milk product. It's a synthetic plastic.

Examples of objects made from casein (milk protein) plastic. For commercial use, casein was often mixed with formaldehyde to make galalith, which is stronger than milk plastic made with vinegar.

Materials List

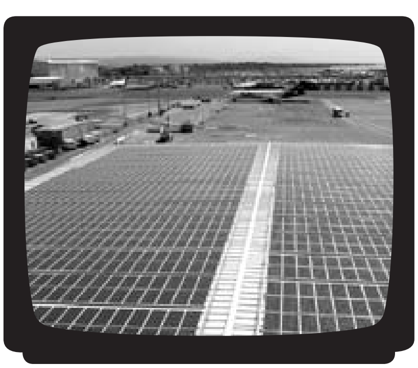
- cheese cubes in a plastic baggie
- cheesecloth or fine strainer
- clear glass cooking pot* or large, glass Pyrex® measuring cup
- container to catch the whey liquid
- copies of the cheese bioplastic recipe (p. 62) for audience to take home
- examples of biodegradable plastics, if available
- examples of casein plastics, if available
- hand wipes for visitors who volunteer to mold the bioplastic
- hot plate, microwave, or other heat source (or preheat the milk to more than 37°C/98°F—do not boil or scald—and keep it in a Thermos)
- large spoon for stirring
- milk, 1 cup**
- paper towels
- safety goggles
- scissors (to cut cheesecloth, if using)
- thermometer
- vinegar, 2 tablespoons per cup of milk
- waste bucket for disposing of vinegar solution
- waste basket for disposing of paper towels/hand wipes
- wax paper
- Demonstration Title Sign and applications collage (see Resources)—mount on foam core or insert into a clear plastic display rack
- (optional) NOVA *Making Stuff: Cleaner* video clip (see Resources) and video display equipment

For Resources, visit **pbs.org/nova/education/makingstuff**

* A glass or Pyrex® cooking pot will allow the audience to better see the curdling.

** A cup of milk will yield about a golf-ball sized batch of casein plastic. Adjust the volume of ingredients to the size of your audience using two tablespoons of vinegar per cup of milk.

Showing Video Clips from MAKING STUFF: CLEANER



If you are able to show video at the site of the demonstration, the video clip from NOVA's *Making Stuff: Cleaner* can be used either as an introduction or as a follow-up to your demonstration. The segment could also be played on a continuous loop nearby to draw visitors into the demonstration area.

Advance Preparation

1. At least a day before the demonstration, follow the recipe (p. 67) to **make several casein plastic samples**—or keep samples from previous demonstrations.

2. Before the demonstration, **warm the milk** to at least 37°C/98°F so that it's ready to be used. Don't boil or scald it. If doing multiple demonstrations throughout the day in a venue where no heat source is available, a large batch of milk (at least 2 cups/demo) can be microwaved and kept in a Thermos. Heat the milk for five minutes at 50 percent power and it should remain above 37°C/98°F for several hours.

3. If using cheesecloth rather than a fine strainer, **cut the cheesecloth** into squares large enough to be affixed with rubber bands over the mouth of the container that you will use to strain the mixture, separating the curds from the whey.

4. (optional) **Locate pictures** or samples of casein plastic products—vintage jewelry, buttons, doorknobs, or acrylic paints. Either create a display on a side table or use as visual aids when discussing casein plastic during the demonstration.

5. (optional) **Locate examples** of biodegradable products—such as the new biodegradable plastic bags used for certain kinds of snack chips, compostable soup bowls containing polylactic acid (PLA) plastic, or other PLA products if available in your area. Either create a display on a side table or use as visual aids when discussing biodegradable materials during the demonstration.

6. (optional) If screening a video clip, **set up a monitor** and DVD player at the demonstration site.

7. **Post** the Demonstration Title Sign on the cart/table.

SAFETY NOTES

- Stress that cheese is safe to eat because it's made of 100 percent food products. Commercial bioplastics (containers, bags, etc.) often also contain non-bio materials. ***DO NOT*** eat them.
- Keep pure vinegar and any heat source at a safe distance from visitors.
- Make sure your curds cool completely before handling, about three minutes.
- Because the take-home recipe requires heat, children should only use it under the direct supervision of an adult.
- Vinegar can sting eyes on contact, and so should only be handled by an adult.

Demonstration Script

PART 1 – DEFINE BIOPLASTIC

1. **Welcome visitors** to the demonstration and briefly introduce the show. "*Welcome to this* Making Stuff *demonstration*. Making Stuff: Stronger, Smaller, Cleaner, Smarter *is a four-part NOVA series on materials science that will air on PBS in January 2011. This demonstration accompanies the Making Stuff: Cleaner episode*."

2. **Define plastic.** *"What is plastic?"* Solicit some answers and then say: *"The word plastic has many meanings. It can describe anything that is molded or shaped. But scientifically, a plastic is a type of polymer, a substance made of long chains of molecules. Polymers can be natural or artificial (synthetic)."*

3. **Discuss plastic's origin.** *"Where does plastic come from?"* Most will know it is artificial or synthetic but many may not know it is petroleum-based. Solicit some answers and then say: *"Most plastics today are synthetic (or artificial) plastics made from petroleum (just like oil and gas)."*

4. **Define bioplastic.** Hold up the plastic bag containing the cheese and say: *"What I have here is a bioplastic."* (Don't define the word yet or reveal that it is cheese.) Demonstrate how plastic it is. Bend it, squeeze it, roll it into a ball. Let visitors handle the bag. Ask: "*What does* bio *mean*?" Maybe someone is learning *bio*logy? Or writing a *bio*graphy? Explain that *bio* means "life" and this bioplastic (hold up the plastic baggie containing the cheese) came from a living thing—a plant or animal. Ask: *"Any guesses where it came from?"* Announce: *"This bioplastic is—guess what, folks?—ordinary cheese, which is made from milk that came from cows. Cheese is a natural polymer, a bioplastic."*

5. **Expand the scope of inquiry.** *"Why would a plastic made from plant or animal materials be good?"* Some answers are:
   - A plastic made from natural materials will break down more easily in the environment (if you can eat it, so can bacteria and other microbes that break down living things, which is why we refrigerate cheeses to slow down this process).
   - Also cows keep making milk, so this bioplastic is a renewable resource.

6. **Sum up.** Field any other questions and then say: *"Now let's make a bioplastic."*

Q How is synthetic plastic made?

A Most synthetic plastics are chemically derived from petroleum. Hard plastics are molded during a semi-liquid state and then hardened. Non-bioplastics can remain buried in landfills for hundreds or thousands of years and are generally not biodegradable (microbes do not break them down).

PART 2 – MAKE INSTANT CHEESE BIOPLASTIC

1. **Engage the audience** by holding up containers of milk and vinegar and announcing: *"I'm about to turn these two ordinary liquids, milk and vinegar, into a solid bioplastic—in an instant!"* See who believes you.

2. **Introduce vinegar.** Explain that vinegar is an acid. Don the safety goggles and **explain** that you are wearing safety goggles because pure vinegar is an acid, which is a powerful chemical that can sting your eyeballs.

3. **Introduce milk.** Hold up the milk and explain: *"Milk is a kind of liquid that has solids suspended in it, including fats and proteins that a human body needs. The protein found in milk is called casein."* (*Casein* is pronounced "kay-seen".)

4. **Ask for predictions.** The curdling really will happen in a flash, and you don't want a single onlooker to miss it. **Ask**: *"What do you think will happen when we mix the two liquids?"*

5. **Curdle the milk.** Add the vinegar with a flourish and stir for a minute or two until the curds are well formed. (This happens at about pH 4.7; milk's normal acidity is pH 6.5.) Hold up the container to show the result.

6. **Explain the science.** Say: *"What just happened was that the vinegar caused the casein proteins in the milk to unfold and reorganize into long chains of molecules called a polymer. So this is an example of a natural polymer—a bioplastic."*

7. **Strain the mixture.** Pour the mixture through the strainer or cheesecloth, allowing the whey to collect in a container; squeeze the vinegar out of the curds and let the curds cool (about 2-3 minutes).

8. **Share the casein samples.** While the newly made bioplastic cools, pass around your pre-made sample(s), field questions, and share the below facts:
   - The vinegar, with a boost from heat, causes proteins called caseins to drop out of the liquid and clump together. It does this by dissolving the calcium that binds casein proteins, which then join together in very long and strong chains (polymers).
   - The fact that bacteria eat milk makes this plastic *biodegradable*—microbes break it down.

9. **Hands-on bioplastic.** Invite a volunteer to take a handful of the *fully cooled* curds and press and shape it into a figure—which you can use for the next demonstration. Point out that the plastic will harden, like your casein artwork, in a couple of days. Offer the visitors who handled the material some wet hand wipes to clean the vinegar smell.

10. **Conclude the demo.** Emphasize that this is just one example of a simple, homemade bioplastic. Not all bioplastics are milk-based; others are made from cellulose, soy protein, hemp fiber, or flax fiber and commercial production is much more complicated. Share some applications of bioplastic including utensils, plates, cups, bowls, and packaging such as snack chip bags. Remind visitors to pick up a take-home recipe and to use it with adult supervision.

When vinegar is added to milk, a bioplastic forms.

Q Can you eat this bioplastic?

A Yes, but it wouldn't taste very good. This substance is a precursor to cheese. A cheese called paneer is made by adding acid to hot milk. The curds are squeezed, drained, or soaked in cold water for hours to change their texture. Other cheeses are formed by rennet—an enzyme from the stomachs of cows and sheep that curdles milk.

Applications

Applications of Bioplastic

- packaging
- disposable food service items such as cups, plates, containers, and cutlery
- bags
- water bottles
- diapers
- carpet
- car interiors

Glossary

- **biodegradable**–able to be broken down safely in the environment by microbes or natural processes
- **bioplastic**–a plastic made from plant or animal material that is biodegradable
- **casein**–a protein found in milk that can be used to make bioplastic
- **plastic**–the common term for a polymer; plastics can be natural or synthetic
- **plasticity**–the ability to be molded or shaped
- **polymer**–long chains of molecules
- **polymerization**–the process by which a polymer is formed

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Take-Home Recipe for Instant Cheese Bioplastic

INGREDIENTS

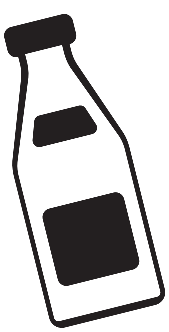
- 1 cup of milk*
- 2 tablespoons of vinegar for each cup of milk
- spoon for stirring
- cheesecloth (works best) or fine strainer
- container (to strain the mixture)
- paper towels for clean up
- (optional) a drop or two of glycerin

*One cup of milk makes about a golf ball-sized plastic sample. Recipe can be increased as needed.

FROM THE KITCHEN OF MAKING STUFF

DIRECTIONS

1. Pour the milk into a pan and warm it on the stove. Be careful not to boil or scald it. (If a skin develops, start over.)
2. Move the pan from the heat.
3. Add vinegar to the warm milk and stir until it separates and the curds are well formed (about 1–2 minutes).
4. Strain the mixture through the cheesecloth or a fine strainer.
5. Wait for the strained curds to completely cool (2–3 minutes).
6. Wrap the curds in the cheesecloth or hold them between your hands and squeeze out the extra liquid.
7. The curds will be crumbly at first—press and knead them into a solid plastic. (A drop or two of glycerin will help to "plasticize" the mixture.)
8. Shape the plastic as you like—you may want to use cookie cutters to cut shapes. Let dry overnight.



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