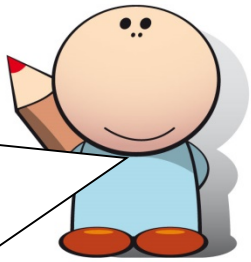


"Plastic made from milk or potatoes", that certainly sounds like something made-up. If you agree, you may be surprised to learn that in the early 20th century, milk was used to make many different plastic ornaments, including jewelry for Queen Mary of England. In this chemistry science project, you can figure out how to make your own milk and/or potato plastic and use it to make beads, ornaments, or other items.

TURNING MILK INTO PLASTIC

INTRODUCTION

What can you make out of milk? Cheese, butter, whipped cream, sour cream, yogurt, ice cream, and...plastic! Are you surprised by plastic? It is true. In fact, from the early 1900s until about 1945, plastic made from milk was quite common. This plastic, known as **casein plastic** or by the trade names Galalith and Erinoid, was used to manufacture buttons, decorative buckles, beads, and other jewelry, as well as hand-held mirrors and fancy comb-and-brush sets. Figure 1 shows examples of belt buckles made from casein plastic in the 1930s and '40s.

Figure 1 *Decorative belt buckles manufactured from casein plastic in the 1930s and '40s.*

But how can milk be changed into plastic? To answer that we need to think first about what plastic is. The word **plastic** is used to describe a material that can be molded into many shapes. Plastics do not all look or feel the same. Think of a plastic grocery bag, a plastic doll or action figure, a plastic lunch box, and a disposable plastic water bottle. They are all made

of plastic, but they look and feel different. Why? Their similarities and differences come from the molecules that they, like everything else, are made of. **Molecules** are the smallest units (way too small to see with your eye!) of any given thing. Plastics are similar because they are all made up of molecules that are repeated over and over again in a chain. These are called **polymers**, and all plastics are polymers. Sometimes polymers are chains of just one type of molecule, as in the top half of Figure 2. In other cases polymers are chains of different types of molecules, as in the bottom half of Figure 2, that link together in a regular pattern. A single repeat of the pattern of molecules in a polymer (even if the polymer uses only one type of molecule) is called a **monomer**.

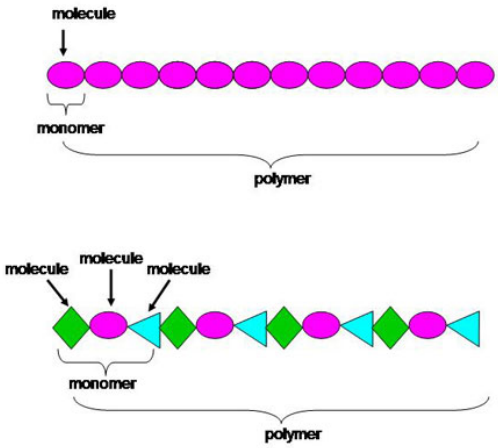


Figure 2 *The top image shows a polymer where the monomers are just one type of molecule. The bottom image shows a polymer where the monomers are made up of three different molecules. In both polymers, the monomers link in a repeating pattern.*

Milk contains many molecules of a protein called **casein**. When you heat milk and add an **acid**, the casein molecules unfold and reorganize into a long chain. Each casein molecule is a monomer and the polymer you make is made up of many of those casein monomers hooked together in a repeating pattern like the top example in Figure 2. The polymer can be scooped up and molded, which is why it is a plastic.

In this chemistry science project, you will investigate what is the best recipe for making casein plastic by making batches of heated milk with different amounts of vinegar. How much vinegar is needed to give you the most plastic? Without enough vinegar the casein molecules do not unfold well, making it difficult for them to link together into a polymer. Of course, if you were manufacturing you would be thinking about both the amount of plastic you can make and the cost. The more of any ingredient you use the more expensive the end product is. The "best" recipe will have the highest **yield** (make the most plastic) for the smallest amount of vinegar.

The plastic you make will be a bit more crumbly and fragile than Galalith or Erinoid. That is because the companies that made those casein plastics included a second step. They washed the plastic in a harsh chemical called *formaldehyde*. The formaldehyde helped harden the plastic. Although you will not use formaldehyde because it is too dangerous to work with, you will still be able to mold the unwashed casein plastic you make. Once you have a recipe, with the best ratio of vinegar to milk, for your casein plastic, you can have fun with it. Try shaping it, molding it, or dyeing it to make beads, figures, or ornaments, such as those shown in Fig. 3.

Figure 3 *Casein plastic*

MATERIALS

- Milk (1 cup = 250 ml)
- White vinegar (20ml)
- Measuring cylinders
- Paper towels/ coffee filter
- Spoon
- Optional: Cookie cutters, glitter, food coloring, markers
- Cooking pot
- Heating plate

METHOD

- Gently heat 250 ml milk in a cooking pot using the heating plate until the milk is steaming.

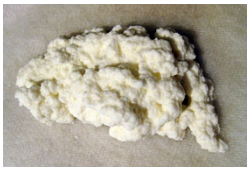
- Add 20 ml of white vinegar. You should see the milk form white clumps, these are called curds.

  Why do you think the milk forms curds when adding the vinegar? What do you think they are made of?

- Mix the milk and the vinegar slowly with a spoon for a few seconds.

- Pour the milk and vinegar mixture through a coffee filter

- Once the milk and vinegar mixture has cooled a bit, use a spoon to scoop out the curds. You can do this by tilting the spoon against the inside of the pot to let excess liquid drain out while retaining the curds in the spoon. Collect as many curds as you can in this way and put them on top of the paper towel stack.



- Fold the edges of the paper towel stack over the curds and press down on them to absorb excess liquid from the curds. Use extra paper towels if needed to soak up the rest of the extra liquid.
- Knead all of the curds together in a ball of dough. This is the casein plastic.

How do the kneaded curds feel? Do they look differently than the curds originally did?

If you want to make the casein plastic into something, you can color, shape, or mold it now (within an hour of making the plastic dough) and leave it to dry on paper towels for at least 48 hours. Once it has dried, the casein plastic will be hard. *Tip:* To shape the plastic, the dough must be kneaded well. Molds and cookie cutters work well, or, with more patience, the dough can be sculpted. Food coloring, glitter, or other decorative bits can be added to the wet casein plastic dough, and dried casein plastic can be painted or colored with markers.

CLEAN UP

To avoid clogging the sink discard any unused curds in the trash. Do not pour them down the sink.

WHAT HAPPENED

When you added the hot milk to the vinegar, small, white chunks should have become visible in the mixture. This is because adding an acid, such as vinegar, to the milk changes the pH of the milk and makes the casein molecules unfold and reorganize into a long chain, curdling the milk. The white chunks are curds. You should have been able to use a spoon to separate the curds from most of the liquid. Additional drying of the curds with the paper towels should have made the curds ready to knead in to a ball and use as casein plastic, which can be molded and decorated.

DIGGING DEEPER

Plastics are a group of materials that can look or feel different, but can all be molded into many shapes. The similarities and differences between different plastic products come down to the molecules they are made of. Plastics are all similar because they are all made up of molecules that are repeated over and over again in a chain, called a polymer. Polymers can be chains of one type of molecule, or chains of different types of molecules linked together in a regular pattern. In a polymer, a single repeat of the pattern of molecules is called a monomer (even if the polymer is made up of only one type of molecule).

Milk contains many molecules of a protein called casein. When milk is heated and combined with an acid, such as vinegar, the casein molecules unfold and reorganize into a long chain. Each casein molecule is a monomer and the chain of casein monomers is a polymer. The polymer can be scooped up and molded, which is why plastic made from milk is called casein plastic.

MAKE IT YOUR OWN

- How does the amount of vinegar used affect the yield of casein plastic? To find out you can repeat this activity, but in addition to testing 20 ml of white vinegar with 240ml of hot milk, try also testing 5ml, 10ml, or 40ml of white vinegar, each with 240 ml of hot milk. To collect more of the curds and get a better idea of the yield of the casein plastic, instead of scooping out the curds with a spoon, you can pour the vinegar and milk mixture through a piece of cotton cloth (such as an old T-shirt) secured with rubber bands on top of a cup.
- In addition to vinegar, there are a lot of other acids that we encounter in the kitchen all the time, such as lemon juice, orange juice, soda pop, and tomato juice. Do some of these common acids work better than others to make casein plastic?
- You used hot milk in this activity that was not a specific temperature, but using hotter or colder milk might affect the casein plastic reaction. Design an experiment to investigate this. How does the temperature of the milk affect how much casein plastic you can produce?

TURN POTATO STARCH INTO PLASTIC

- **EXTRACTING THE STARCH**

MATERIALS

- 100 g of clean potatoes
- A grater
- Strainer or sieve
- A spoon

- Distilled water
- Pestle and mortar
- Measuring cylinder (100 ml)
- Beaker (500 ml)
- Heating plate

METHOD

- Grate about 100 g potato. The potato does not need to be peeled, but it should be clean.
- Put the grated potato into the mortar and add 100 ml of distilled water. Grind the potato carefully.
- Pour the liquid off through the strainer into the beaker, leaving the potato behind in the mortar.
- Repeat step 2, by adding again 100 ml of distilled water to the potato, grind and strain.
- Leave the mixture to settle in the beaker for 5 minutes.
- Decant the water from the beaker, leaving behind the white starch which should have settled to the bottom.
- Add 100 ml of distilled water to the starch and stir gently.
- Leave to settle again and then decant the water, leaving the starch behind.

Now, you can use the starch to make a plastic film.

➢ MAKING THE PLASTIC

In this activity you will make a plastic film from potato starch and test its properties. Potato starch is a polymer made of long chains of glucose units joined together. It actually contains two polymers: Amylose, which is a straight chain of glucose units and amylopectin, which is a branched polymer, also made of glucose units. The amylopectin prevents the starch from becoming plastic-like. You will use hydrochloric acid to break down the amylopectin and change the structure and properties of the polymer. You will make two different batches of the potato plastic. In one you will add some propan 1,2,3-triol (also known as glycerol), which will act as a plasticiser. In the other batch, you will leave the propan-1,2,3-triol out.

MATERIALS

- A cooking pot
- A large watch glass
- Heating plate
- A spoon
- Potato starch
- Propan-1,2,3-triol
- Hydrocholric acid 0.1 mol/l
- Sodium hydroxide 0.1 mol/l
- Balance

- Measuring cylinder (25 ml and 10 ml)
- Petri dish
- pH indicator paper
- **Eye protection**

METHOD

- Put 25 ml water into the cooking pot and add all the starch, 3 ml hydrochloric acid and 2 ml propan-1,2,3-triol.
- Bring it carefully to the boil and then boil it gently until it is gel-like. Make sure it does not boil dry – if it looks like it might, then stop heating.
- Measure the pH
- Add enough sodium hydroxide solution to neutralize the mixture, test the pH after each addition. (You will probably need to add about the same amount of sodium hydroxide as you did acid at the beginning).
- If you wish you can add a drop of food coloring and mix thoroughly. Be careful not to spill the food coloring – it stains.
- Pour the mixture onto a labelled petri dish and push it around with the spoon, so that you have an even covering.
- Let it dry out on a radiator or sunny windowsill (this might take a day or two)

  Repeat the steps described above, but leave out the propan-1,2,3-triol. Make sure you label your mixtures, so that you know which one contains the propan-1,2,3-triol and which one does not.

Extracting starch from potatoes takes a lot of energy. You had to grate the potatoes, grind them and rinse them several times. Similar processes are used in industry to extract starch, although sweetcorn (maize) is used more often than potatoes. The leftover bits are often used in animal feed so that none of the material is wasted.

Name of product	Price in £ per kg
Starch/PVA blend	3.40–4.40
polythene	0.50–0.60
polystyrene	0.60

Figure 4 *Price list*

Plastics made from plants or other living things are known as bioplastics. 'Bioplastic' does not mean the same thing as 'biodegradable plastic'. Some biodegradable plastics are made from oil and some bioplastics are not biodegradable.