https://doi.org/10.29013/AJT-22-5.6-56-61

Capo Kristiana,
Chemistry engineer,
University of Barcelona, Spain

REDUCED USAGE OF PLASTIC, CHOOSING/SELECTING ALTERNATIVE METHODS FOR ITS PRODUCTION

Abstract. "Plastic made from milk" – 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 the best recipe to make your own milk plastic (usually called casein plastic) and use it to make beads, ornaments, or other items.

Keywords: plastic, polymer, alternative methods of plastic production, casein plastic.

Objective. In this chemistry science project, you will investigate which is the best recipe for making plastic out of milk.

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 1900 s 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 fountain pens and 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; more examples can be found in the references in the Bibliography.

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.

Figure 1. These decorative belt buckles were all manufactured from casein plastic in the 1930s and '40s. (Photograph courtesy of Galessa's Plastics Photostream, 2010)

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.**

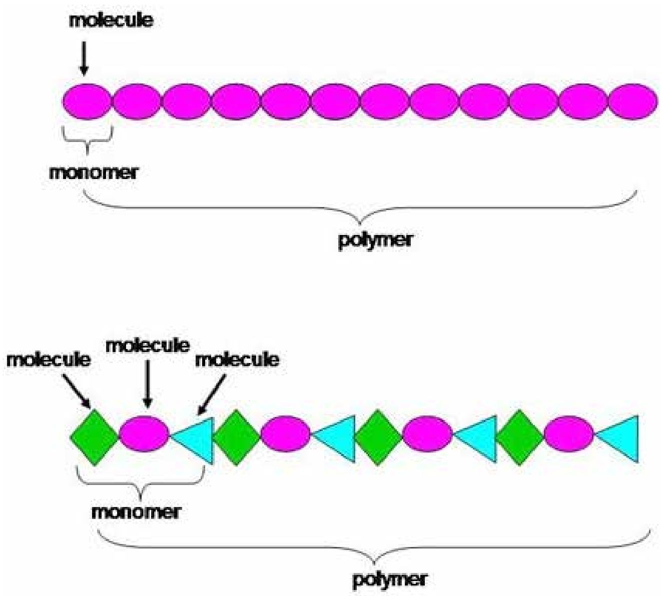

Figure 2. The top image shows a polymer where the monomers are just one type of molecule.

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** (in our case vinegar), 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 (all pink) 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 at home, 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 (Figure 3).

Figure 3. The casein plastic you will make in this project can be used to make beads, figures, or ornaments like the ones shown here.

You can also choose to take a green chemistry angle to this project. The goal of **green chemistry** (also called sustainable chemistry) is to make chemical reactions and products using the most environmentally friendly methods. There are twelve principles of green chemistry that help scientists do that. This project already deals with one of them – the idea that the raw materials (called *feedstocks*) for a reaction or product should be renewable. To be renewable, a material has to be something you can get again easily, and you won't run out of it. Milk is more renewable than petroleum and natural gas, which are the traditional raw materials for plastic. Both oil and natural gas are made by geological processes that take millions of years to occur; once we use up all of the oil and natural gas on Earth, it will take millions of years for more to be created. Another green chemistry principle is *designing for degradation*. Meaning that scientists and chemical engineers should think about how a product will degrade (break down over time) and make sure that it is degrading over a reasonable amount of time and in a way that does not harm the environment. Traditional plastics are not green, it takes hundreds of years for them to decompose, and in the process, they break up into smaller and smaller pieces that can be swallowed by other living things and harm them. Is your milk-plastic better? Will it degrade? Check the variations for this project for ways to answer that question.

Experimental Procedure

Terms and Concepts

- Casein plastic
- Plastic
- Molecule
- Polymer
- Monomer
- Casein
- Acid
- Yield
- Curds
- Green chemistry

Materials and Equipment

The materials listed below are for doing the experimental procedure exactly as written. However, you can make changes to the experimental procedure in order to use a different size measuring cup and/or a stovetop rather than a microwave.

1. Mugs or other heat-resistant cups (4); they should all be identical so as not to introduce another variable (See What are Variables? How to use them in Your Science Projects), and large enough to hold more than 8 oz. of liquid

2. Masking tape

3. Pen or permanent marker

4. Teaspoon measuring spoon

5. White vinegar (at least 8 oz.)

6. Milk (at least 12 cups); nonfat, 1%, 2%, and whole milk will all work

7. Microwavable liquid measuring cup; should be large enough to hold 4 cups of milk like this one from Amazon.com

8. Microwave

9. Cooking or candy thermometer, such as this one from Amazon.com

10. Spoons (4)

11. Cotton cloth (12 squares, each 6 x 6 inches); cutting up old T-shirts works just fine

12. Rubber bands (4)

13. Clear plastic or glass drinking cups (4), each large enough to hold 8 oz. of liquid

14. Kitchen scale, should be accurate to 1 gram, such as this one from Amazon.com

15. Wax paper (in 12 identical pieces); each piece should be smaller than the weighing surface of the kitchen scale

16. Paper towels

17. Lab notebook

18. Optional (for fun): molds, cookie cutters, food coloring, paint, glitter, permanent markers

Experiment number 1

Making Casein Plastic

This experiment uses hot liquids, so an adult's help will be needed throughout.

1. Using the masking tape and pen, label the four mugs: 1, 2, 4, and 8.

2. Use the measuring spoon to add 1 teaspoon (tsp.) of white vinegar to the mug labeled "1," 2 tsp, to the mug labeled "2," 4 tsp. to the mug labeled "4," and 8 tsp. to the mug labeled "8."

3. Heat 4 cups of milk (1 quart) in a large measuring cup in the microwave.

a) The exact amount of time needed will depend on your microwave. Start by warming the milk at 50% power for five minutes. The 50% power will help you avoid scalding (burning) the milk.

b) Have an adult check the milk with a thermometer to make sure it is *at least* 49 °C (120°F). If it is not heated enough, put it back in the microwave for another two minutes at 50% power. Repeat this step until the milk is hot. Warmer than 49 °C is fine.

c) In your lab notebook write down the total number of minutes it took you to warm the milk and the final temperature of the hot milk. When you repeat these steps later you should try to get as close to these numbers as possible. 1 or 2 degrees warmer or cooler is fine as long as the milk is *at least* 49 °C.

4. Carefully pour 1 cup of hot milk in to each of the four mugs with vinegar in them. (You may need to ask an adult to pour the hot milk for you.) What do you see happening in each mug? Write down your observations in a data table, like Table 1 below, in your lab notebook. In at least one of the mugs you should see that the milk has separated into white clumps (called **curds**).

a)Make sure to pour the milk in to all four of the mugs at the same time so that the milk is the same temperature across all four vinegar amounts.

Table 1.– Make a table like this in your lab notebook to write down your data. Make a new table for each repeat of this experiment, for a total of three tables

Number teaspoons of vinegar	**Forms curds? (yes/no)**	**Describe liquid after sieve**	**Weight of casein plastic (in grams**	**Write down any other observations**
1				
2				
4				
8				

5. Mix each mug of hot milk and vinegar slowly with a spoon for a few seconds. That will help make sure the vinegar reacts with as much of the milk as possible.

6. Meanwhile, take one of the cotton-cloth squares and attach it with a rubber band to the top of one of the clear cups so that it completely covers the cup's opening. This will make a *sieve* as shown in Figure 4 below.

a) Make sure the cloth hangs down a bit inside the cup so that you have room to pour liquid in.

b) Repeat this step with the other three clear cups.

c) Label the clear cups 1, 2, 4, and 8 with the tape and pen.

7. Once the milk and vinegar mixture has cooled a bit, carefully pour the mixture from mug "1" into the cotton cloth sieve on cup "1." If there are any curds, they will collect in the cloth sieve. The leftover liquid will filter into the clear cup. Figure 4 below shows what the setup looks like. Where do you think the casein is, in the liquid in the cup or the curds in the sieve? *Tip:* You may want to do this step over a sink just in case any of the liquid spills.

8. In your table in your lab notebook, write down what the leftover liquid in the clear cup looks like. What color is it? How clear is it? Be sure to write the information down for each cup on the corresponding line on the table (for instance, cup "1" for the cup with 1 tsp. of vinegar, and so on).

9. Over a sink, carefully remove the rubber band sieve on cup "1." With your hands, squeeze all the extra liquid out of the curds. Scrape the curds off of the cloth and knead them together, as you would bread dough, into a ball. This is your casein plastic. Before it dries, the ball of dough will look similar to (Figure 5) below.

Figure 4. A piece of cotton cloth and a rubber band are used to make a sieve at the top of a clear glass. Once the milk and vinegar mixture is poured into the sieve, the curds will gather on the top of the sieve, and the liquid will drain through into the clear cup

Figure 5. The wet casein plastic will form a lumpy ball of whitish dough like the one shown here

10. Weigh the ball of casein plastic on a kitchen scale (set for grams) using a piece of wax paper to keep the scale clean. Record the weight in your table.

a) When weighing, remember to turn on the scale and first make sure it reads zero with nothing on it. This will help make sure your measurements are accurate. Also, use a new sheet of wax paper each time you weigh a different ball of casein plastic. This will give you exact weights (without crumbs and liquid from the last ball).

b) The amount of casein plastic each recipe makes is called the **yield** for that recipe. The more plastic, as measured by weight in this case, the greater the yield.

11. Repeat steps 7–10 for the other three mugs of milk and vinegar.

12. If you want to make your casein plastic into something, you can color, shape, or mold it now (within an hour of making the plastic dough) and then leave it to dry on some paper towels for at least 48 hours. See the "Ideas for Fun with Casein Plastic" for more suggestions.

13. For your science project you will want to repeat steps 1–11 again two more times. This will give you enough data to see whether one recipe reliably yields more casein plastic than another.

Analyzing Your Data

1. Calculate the average yield (amount in grams) of casein plastic made from each recipe. If you do not know how to average, ask an adult to show you.

2. Make a bar graph showing the average yield for each recipe. You can make the bar graph by hand or use a website like Create A Graph [4] to make the graph on the computer and print it.

a) On the left axis (the y-axis) write the average yield of casein plastic. Make a bar along the x-axis for each of the four recipes you tested.

3. When you look at your observations about the liquid left over after straining out the curds, do the weights of the yields make sense? Why or why not?

4. Which recipe yielded the most casein plastic on average? Was any other recipe a close second? Based on this data, which do you think is the "best" recipe in terms of yield?

Ideas for Fun with Your Casein Plastic

Try making beads, ornaments, or figurines out of your casein plastic. You should do the molding and coloring steps (except for paint and/or marker) within the first hour of making the plastic or it will start drying out.

1. Shaping the plastic:

a) Knead the dough well before shaping it.

b) Molds and cookie cutters work well on the wet casein plastic.

c) You can also sculpt the wet casein plastic into figures, but it takes a bit more patience.

1. Coloring the plastic:

a) Food coloring, glitter, or other decorative bits can be added to the wet casein plastic dough. The beads in Figure 3 above were made from casein plastic dough that had yellow food coloring and multicolored glitter kneaded into it.

b) Dried casein plastic can be painted or colored on with markers. The smiley face in Figure 3 is on uncolored casein plastic and was drawn on using a black permanent marker.

1. Hardening the plastic:

a) Casein plastic will be hard once it has dried.

b) Drying time varies depending on the thickness of the final item (thicker pieces take longer), but most casein plastic requires at least two days to become hard.

Variations

How does the temperature of the milk affect how much casein plastic you can produce? Design an experiment to find out.

In this science project you added vinegar, an acid, to milk to make casein plastic. There are a lot of other acids you can probably find around the house, such as lemon juice, orange juice, soda pop, and tomato juice. Do some of these acids work better than others to make casein plastic? Design an experiment to find out. *Tip:* To learn more about acids and bases, see Acids, Bases, & the pH scale by Science Buddies.

If you are interested in making another fun polymer, try the Slime Chemistryproject.

How well does your milk plastic degrade? Try setting up a compost bin and comparing how well your milk-plastic decomposes compared to traditional plastic and biodegradable/compostable plastic. Make sure to use pieces of the different types of plastics which are similar thicknesses and shapes. For example, you could make the head of a spoon out of milk plastic and compare it to other types of plastic spoons.

References:

1. These resources have more information about, and photos of, casein plastic: Morgan, J. (2001, June 11). Welcome to the Caseino. Retrieved July 30, 2012.
2. Plastics Historical Society. (2011). Casein. Retrieved July 30, 2012.
3. This website is a fun introduction to polymers: Polymer Science Learning Center, University of Southern Mississippi. (2012). What is a polymer?. Retrieved July 26, 2012.
4. For help creating graphs, try this website: National Center for Education Statistics, (n.d.). Create a Graph. Retrieved June 25, 2020.