Teaching notes

In this activity, learners use potato starch to produce a plastic. They learn about each ingredient and why it is added. The practical is straightforward – common household equipment and items purchased at the supermarket can be used to make this bioplastic.

Find a presentation for learners and curriculum links at: rsc.li/3XDyQTR

Equipment and preparation

Depending on the size of the group and the amount of equipment to hand, the practical takes 10–25 minutes to complete and is suitable to be carried out in pairs or threes. The plastic takes roughly seven days to dry, therefore it is recommended that you try the practical beforehand and take in some pre-prepared samples for discussion.

All the ingredients can be purchased from supermarkets or online. The experiment can be carried out in a kitchen, classroom (with adequate heating facilities), home economics space or laboratory.

You will need:

- Water
- Potato starch
- Vegetable glycerine (also known as glycerin or glycerol)
- Vinegar
- Teaspoon or access to a laboratory balance
- Tablespoon or access to measuring cylinders
- Bowl or beaker
- Spatula or glass rod
- Pan or beaker
- Food colouring (optional)
- Stove or stirrer hotplate
- Greaseproof paper
- Foil
- Safety glasses or goggles

Method

If you are in a laboratory, you can use glassware, balances and measuring cylinders. If you are not, you can use baking measures. Both methods are listed below.

Non-laboratory setting

1. Take 1 level tablespoon of potato starch and place in a bowl.
2. Add 7 tablespoons of water to the bowl and stir.
3. Add 2 teaspoons of vinegar to the bowl.
4. Add 2 teaspoons of glycerine to the bowl and stir.
5. (Optional – add 2 drops of food colouring and stir).
6. Pour the mixture into a pan, put it on the stove on a medium-high heat and stir continually.
7. Stir with a plastic spatula until the mixture thickens. Do not let the mixture boil dry.
8. When jelly-like, pour onto greaseproof paper with foil underneath.
9. Flatten with a spatula to roughly 8 inches in diameter, taking care to make the thickness even all over.

Laboratory setting

1. Take 15 g of potato starch and place in a beaker.
2. Add 100 cm^3 of water to the beaker and stir.
3. Add 10 cm^3 of vinegar to the beaker.
4. Add 10 cm^3 of glycerine to the beaker and stir.
5. (Optional – add 2 drops of food colouring and stir).
6. Place the beaker on a hotplate (or equivalent heating method, depending on availability) on a medium-high heat and stir continually.
7. Stir with a glass rod until the mixture thickens. Do not let the mixture boil dry.
8. When jelly-like, pour onto greaseproof paper with foil underneath.
9. Flatten with a spatula to roughly 8 inches in diameter, taking care to make the thickness even all over.

Leave the plastic to dry for at least 7 days. Do not leave it anywhere exposed to extremes of heat, or it will likely crack.

Safety and hazards

Carry out your own risk assessment, after consulting with the school. The red risk assessment template that the Royal Society of Chemistry uses for external events can be found here: rsc.li/4ejeqES, but use any template that suits your needs.

Health and safety considerations

- Wear eye protection (safety glasses or goggles) throughout.
- The hotplate or pan is a burn risk.
- The mixture becomes very hot and is a burn risk.
- Glass beakers and glass rods are a burn and shatter risk.
- Use minimum quantities of chemicals.
- Potato plastic should not be eaten.
- Dispose of potato plastic in compostable waste.

Top tips

- Practice making the plastic before the session. Show all the batches you make to the learners after the experiment to demonstrate what theirs will look like when it's dry, even ones that didn't work as well as you were expecting.
- Consider doing the experiment along with the learners. Get them all to complete each step before moving onto the next one. This means no one gets left behind and everyone understands the instructions you're giving them.
- Do not let the mixture boil dry; it 'pops' and tends to jump out of the pan or beaker. This is why everyone doing this experiment should wear eye protection.
- You can substitute corn starch for potato starch, but the resulting plastic is less robust, more opaque and tends to break apart.

Suggested discussion prompts

Questions to ask learners during the experiment:

- What did the mixture look like before and after heating? (Slack, opaque liquid before and thicker, less-cloudy, semi-solid after heating.)
- Why do we add vinegar and glycerine? (Vinegar breaks the branched amylopectin in the potato starch into smaller, straight chains so they can form a plastic. Glycerine acts as a plasticiser by getting in between the polymer chains and makes the final product more flexible and less likely to shatter.)
- How long does it take for the plastic to be touch-dry? What would affect that? (As it cools, it quickly becomes tacky. Spreading it thinner would accelerate the drying process.)
- What changes could you make to the method? (Using different food sources, not adding vinegar or glycerine to see what effect it has, varying the quantities of dry and liquid ingredients, not stirring the mixture during heating or pouring the heated mixture into moulds to make useful products.)

Questions to ask learners after the experiment:

- What would be the best use for these plastics? (Learners may suggest plates, cutlery, alternative to shrink wrap, plastic bags, cups, bowls, pens, hairclips, drinking straws.)
- How long do you think it takes them to decompose? What would accelerate that? (You could measure their decomposition in months, rather than years. Exposure to water, heat or being broken apart are examples of what would accelerate that.)
- What would happen if they were accidently eaten by wildlife? (They would have less environmental impact on wildlife. Although we shouldn't eat them, all the ingredients we have used are food-grade.)
- What are the advantages and disadvantages of bioplastics such as these? (Learners may suggest advantages such as: they are made from renewable sources, they are non-toxic, they offer improved food safety, they can be composted and the nutrients returned to the soil. They may suggest disadvantages such as: land required for growing crops competes with that needed for food production, they could be more expensive than fossil fuel equivalents because it's an emerging technology, they may still result in significant greenhouse gas emissions, they won't break down in landfill as the waste is tightly packed together, they may encourage people to drop their litter more).

To extend the session and go into more detail, use this reading and talking heads activity: rsc.li/3k4Vuyg.

Background chemistry

What's the importance of the four ingredients?

- Water loosens the potato starch.
- Potato starch contains amylose, a linear polymer and amylopectin, which is a branched polymer. It's the starch that is key to forming the plastic.
- Vinegar breaks down branched amylopectin into straight chains, which is accelerated by heating. The type of chemical reaction happening here is hydrolysis. This involves the addition of water molecules to break the glycosidic bonds between the glucose molecules within starch and this forms shorter polymers.
- Glycerine acts as a plasticiser and goes in between the starch chains and makes the final plastic flexible, easier to handle and not likely to shatter.

More information about plastics and bioplastics

Plastic products have become indispensable in our society and are applied in various industries including packaging, automotive and electronics. Their properties can be tuned so they can be made to be strong, lightweight and easily shaped. But they cause a problem when they make their way into the wrong environment, such as our natural ecosystem. Plastics take a long time to break down and when they do, they break apart to form microplastics (plastic fragments less than five millimetres long), which have a high probability of being eaten by wildlife.

We use billions of pieces of plastic and we need to be mindful of how we can protect the environment for the future. However, plastic is often the best material for the job. A complementary approach is to build a circular economy for plastic. Currently, waste plastics can be recycled by mechanical or chemical methods, but mechanical recycling generally results in a lower quality of plastic after several cycles (often called downcycling). Chemical recycling can recover naphtha compounds, which are mainly composed of C_5–C_{12} alkanes and smaller amounts of alkenes and aromatics, which can be reused to produce new plastics of equivalent quality. It's a very promising technology but it presents challenges in terms of cost, emissions and efficiency. Plastics are composed of polymers, made of repeating subunits called monomers. Most of them are derived from fossil fuel-based chemicals such as petroleum or natural gas and they degrade very slowly.

Bioplastics are made from renewable biomass materials, such as recycled food waste or vegetable fats and oils. A very small percentage (about one percent) of plastics are made from plant-based materials and it is an emerging market. Life cycle analysis shows that some bioplastics can be made with a lower carbon footprint than their fossil fuel counterparts, but some processes are currently not as efficient. Designing plastics derived from sustainable starting materials offers an alternative to fossil fuel starting materials and chemical scientists are working to offer these suitable alternatives.