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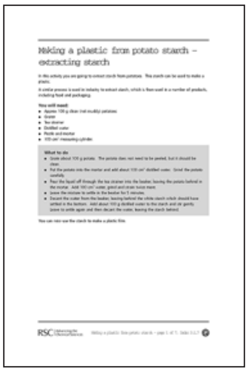
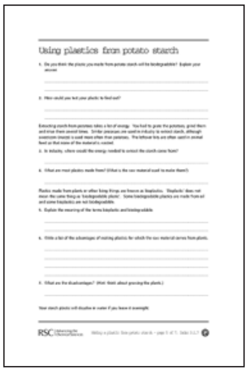
Making a plastic from potato starch


Making a plastic from potato starch – extracting starch


Using plastics from potato starch

Index 3.1.7
7 sheets

In this activity students make a plastic from potato starch and investigate the effect adding a 'plasticiser' has on the properties of the polymer they have made. Students can begin either with potatoes or with commercially bought potato starch. The practical is straightforward; the main hazard is the possibility of the mixture boiling dry.

Timing

Extracting the starch takes about 15–20 minutes and making the plastic about 20 minutes.

Using the activity

This can be used simply as a practical to enhance the teaching of a polymers or plastics topic, it can be used as an introduction to further work on biopolymers and bioplastics and/or it can be used as an example of the effects of plasticisers. A number of student sheets are provided so you can choose to do the whole activity or just selected parts of it.

Extracting starch from potatoes

For each group of students you will need:

- 100 g potatoes
- Grater
- Tea strainer
- Distilled water
- 2 x 400 cm^3 beaker
- Pestle and mortar.

Making the plastic film

For each group of students you will need:

- 250 cm^3 beaker

- Large watch glass
- Bunsen burner and heat proof mat
- Tripod and gauze
- Stirring rod
- Potato starch
- Propan-1,2,3-triol (glycerol)
- Hydrochloric acid 0.1 mol dm^{-3} (**Minimal hazard**)
- Sodium hydroxide 0.1 mol dm^{-3} (**Irritant**)
- Food colouring
- Petri dish or white tile
- Universal Indicator paper
- Eye protection
- Pipettes
- Access to a balance
- 25 cm^3 measuring cylinder
- 10 cm^3 measuring cylinder.

Health and Safety

Wear eye protection.

Propan-1,2,3-triol (glycerol) has no hazard classification but may be harmful if ingested in quantity.

Notes

1. If students have extracted their own potato starch they will need to use about 4 g of it for the next part of the experiment as it is a wet slurry rather than a dry powder. They should add about 22 cm^3 water. If they do not have enough extract then a bit of bought potato starch added to the mix will be fine.
2. If access to a balance is difficult then a heaped spatula of starch can be used rather than 2.5 g.
3. If access to 10 cm^3 measuring cylinders is difficult, 4 pipette squirts of hydrochloric acid and 3 squirts of propan-1,2,3-triol are suitable amounts.
4. If you have a drying cabinet, the plastic film should dry in about 90 minutes at 100 °C.
5. Warn students not to let the mixture boil dry because this can cause it to 'pop' and it shows a tendency to jump out of the beaker. For this reason, students should wear eye protection at all stages of the practical.
6. Food colouring – while use of this is optional, it does enhance the product and the colour makes the plastic film look more like plastic. Only one drop is needed or the film is too dark.
7. If too much water is used, the polymer does not solidify and remains a liquid.

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Explanation

Starch is made of long chains of glucose molecules joined together. Strictly, it contains two polymers: amylose, which is straight chained, and amylopectin, which is branched. When starch is dried from an aqueous solution it forms a film as a result of hydrogen bonding between the chains. However, the amylopectin inhibits the formation of the film. The addition of hydrochloric acid breaks the amylopectin down, allowing a more satisfactory film formation. This is the product formed in the student activity without the addition of propan-1,2,3-triol. The straight chains of the starch (amylose) can line up together and make a good film. However, it is brittle because the chains are so good at lining up – areas of the film can become crystalline, which causes the brittleness.

The addition of propan-1,2,3-triol has an effect because of its hydroscopic (water attracting) properties. Water bound to the propan-1,2,3-triol gets in amongst the starch chains and inhibits the formation of crystalline areas, preventing brittleness and resulting in more 'plastic' properties. In the notes for students, reference to water has been omitted to allow them to concentrate on the effect of the propan-1,2,3-triol itself.

Answers – Making a plastic from potato starch

1. Without propan-1,2,3-triol: a brittle, transparent film is produced. It has probably cracked in the drying process.

   With propan-1,2,3-triol: a plastic, transparent film is produced. It feels slimy and can be bent and manipulated without breaking.

2. The propan-1,2,3-triol has the effect of changing the properties of the product – the propan-1,2,3-triol makes the film flexible and plastic instead of brittle.

3. Students should draw a diagram showing wavy lines all lined up to represent the brittle film. To represent the plastic film, they should draw small molecules in between the polymer chains, which should not be lined up in this case:

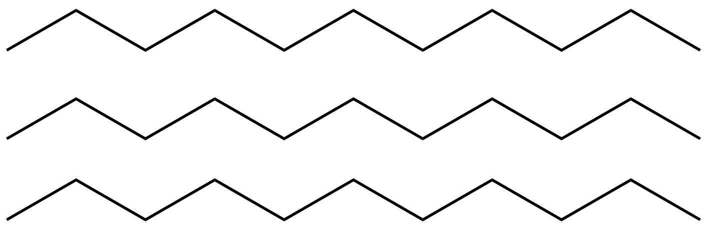

Figure 1 Polymer chains lined up – the product is very brittle

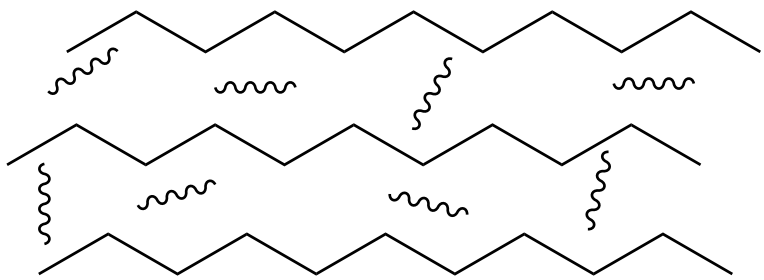

Figure 2 Polymer chains have small molecules between them, which prevents them from lining up

Answers – Using plastics from potato starch

1. Plastic from potato starch will probably be biodegradable because all the starting materials are biodegradable.
2. The plastic could be mixed with some compost, left in a warm place for a few weeks and then examined. If it shows signs of decomposing, it is biodegradable. Another similar answer would be acceptable.
3. The energy needed to extract the starch would come from electricity, which is mostly made from petrochemicals (coal, oil and natural gas.)
4. Most plastics are made from petrochemicals/oil.
5. A bioplastic is a plastic made from a plant or other living thing. Biodegradable means that it is broken down by living things.
6. Plants are renewable raw materials and will not run out; the plastics produced are usually biodegradable; the products can be marketed as 'greener' plastics.
7. Oil is still used up as a lot of energy is needed to produce the bioplastics. Lots of fertilisers are used to grow the crops and these can cause pollution if they get into the water supply.
8. As the plastic is soluble it cannot be used for packing anything that is wet, contains water or is likely to get wet because the packaging will just fall apart. Possible answers could include: not used for packaging drinks, fresh food, plants. Could be used for: packing dry goods, dried food, protective packaging.
9. Mark by impression. Look for a good use of the scientific information and clear communication of the facts.

Making a plastic from potato starch – extracting starch

In this activity you are going to extract starch from potatoes. This starch can be used to make a plastic.

A similar process is used in industry to extract starch, which is then used in a number of products, including food and packaging.

You will need:

- Approx 100 g clean (not muddy) potatoes
- Grater
- Tea strainer
- Distilled water
- Pestle and mortar
- 100 cm^3 measuring cylinder.

What to do

- Grate about 100 g potato. The potato does not need to be peeled, but it should be clean.
- Put the potato into the mortar and add about 100 cm^3 distilled water. Grind the potato carefully.
- Pour the liquid off through the tea strainer into the beaker, leaving the potato behind in the mortar. Add 100 cm^3 water, grind and strain twice more.
- 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 in the bottom. Add about 100 g distilled water to the starch and stir gently. Leave to settle again and then decant the water, leaving the starch behind.

You can now use the starch to make a plastic film.

Making a plastic from potato starch – 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
- 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 stucture 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.

Making the potato plastic

You will need:

- 250 cm^3 beaker
- Large watch glass
- Bunsen burner and heat proof mat
- Tripod and gauze
- Stirring rod
- Potato starch
- Propan-1, 2, 3-triol
- Hydrochloric acid 0.1 mol/dm^3 (**Minimal hazard**)
- Sodium hydroxide 0.1 mol/dm^3 (**Irritant**)
- Food colouring
- Petri dish or white tile
- Universal Indicator paper
- Eye protection
- Access to a balance
- 25 cm^3 measuring cylinder
- 10 cm^3 measuring cylinder.

Health and safety

Wear eye protection.

Propan-1,2,3-triol may be harmful if ingested in large quantities.

What to do

- Put 25 cm^3 water into the beaker and add 2.5 g potato starch, 3 cm^3 hydrochloric acid and 2 cm^3 propan-1,2,3-triol.
- Put the watch glass on the beaker and heat the mixture using the Bunsen burner. Bring it carefully to the boil and then boil it gently for 15 minutes. Make sure it does not boil dry – if it looks like it might, then stop heating.
- Dip the glass rod into the mixture and dot it onto the indicator paper to measure the pH. Add enough sodium hydroxide solution to neutralise the mixture, testing after each addition with indicator paper. You will probably need to add about the same amount of sodium hydroxide as you did acid at the beginning (3 cm^3).
- If you wish you can add a drop of food colouring and mix thoroughly. Be careful not to spill the food colouring – it stains.
- Pour the mixture onto a labelled petri dish or white tile and push it around with the glass rod so that you have an even covering.
- Label your mixture and leave it to dry out. This will take about 1 day on a radiator or sunny windowsill or two days at room temperature.

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 propan-1,2,3-triol and which does not.

Making a plastic from potato starch – examining your plastic

Look carefully at your two petri dishes containing potato plastic.

1. Describe carefully the properties of each of the substances you have made.

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2. What difference has adding the propan-1,2,3-triol made?

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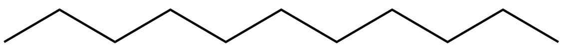
The propan-1, 2, 3-triol is acting as a plasticiser. Plasticisers are used in commercial products to change the properties of the polymer, just as you have used the propan-1,2,3-triol to change the properties of the potato plastic. The propan-1,2,3-triol gets in between the polymer chains and prevents them from lining up in rows to form a crystalline structure. When the polymer becomes crystalline, it also becomes brittle and inflexible. You can think of the plasticiser as a small molecule that gets between the polymer chains and helps them to slide easily over each other so that the polymer behaves like a plastic.

3. Draw a diagram of the polymer chains with and without the propan-1,2,3-triol and use it to help you explain why the potato plastic has very different properties when propan-1,2,3-triol is present. Label which one is which.
Use a simple line like this to represent a polymer chain:



and like this to represent propan-1,2,3-triol.

Using plastics from potato starch

1. Do you think the plastic you made from potato starch will be biodegradable? Explain your answer.

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2. How could you test your plastic to find out?

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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.

3. In industry, where would the energy needed to extract the starch come from?

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4. What are most plastics made from? (What is the raw material used to make them?)

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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.

5. Explain the meaning of the terms bioplastic and biodegradable.

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6. Write a list of the advantages of making plastics for which the raw material comes from plants.

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7. What are the disadvantages? (Hint: think about growing the plants.)

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Your starch plastic will dissolve in water if you leave it overnight.

8. What effect will this solubility have on the number of things that this plastic can be used for? Write down three things for which it could not be used and some things for which it could.

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To try to make starch more useful, researchers have tried blending it with other plastics like polythene. They hoped that this would make the overall product more biodegradable than polythene on its own. Unfortunately, this was not the case. The plastic tended to fall to bits but the pieces were less biodegradable than ordinary starch.

More recently, a scientist called Catia Bastioli from Italy has taken starch treated in the same way that you have treated it (with acid and propan-1,2,3-triol) and mixed it with the polymer PVA (used in white glue). The polymer that results is biodegradable but also water soluble. This means that its use is limited to things like packing dry goods, or replacing polystyrene foam, which is not biodegradable and is made from oil.

The method used to turn the starch into small pieces of foam packaging material is similar to the technique used to make foods such as Rice Krispies and Coco Pops.

Price list

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

9. The letter overleaf was sent to a magazine. The editor does not know much about science and so has asked you to write a reply to be published in the next edition. Make sure that your reply:

- Uses accurate scientific information
- Is clear and concise
- Answers the question.

You may find the following websites helpful when researching your answer. If you use information from a website, do not forget to think about whose website it is and if it is likely to be biased. If so, what effect this bias might have on the information on the site.
http://www.greenlightproducts.co.uk
http://www.friendlypackaging.org.uk
http://www.foe.co.uk/resource/factsheets/plastics.pdf – if you have difficulty with this web address, go to **http://www.foe.co.uk** and follow the links to the plastics factsheet
(All websites accessed in November 2005.)

Dear Editor

I try to be as environmentally-friendly as I can and I like to encourage others to do the same. I found out recently that it is possible to make plastics out of starch from plants, but most plastics are still made out of oil. I am horrified and wondered if you know why this is?

Yours sincerely

Anne Other