UNDERSTANDING YOUR FOOD
the ultimate educational resource

TEACHER NOTES

AO1. Oxygen - friend or foe?

Why has my apple gone brown?

Pupils carry out investigations into conditions for apple browning.

SAFETY NOTE: *SOME ASTHMATICS ARE VERY SUSCEPTIBLE TO SULPHUR DIOXIDE VAPOURS*; THE SODIUM METABISULPHITE SOLUTION MUST BE PREPARED BY A TEACHER OR TECHNICIAN.

The results given are for Bramley cooking apples. The cut surface of a Bramley showed noticeable browning after 10 minutes.

The tasks on sheet AO1 show:

2. The cut surface browns more quickly than the broken surface. When an apple is broken it tends to break between the cells rather than through the cells as is caused by cutting. Breaking the apple causes less cell damage and less discolouration.
3. The pulped apple browns much quicker than the whole apple piece. Pulping produces extensive cell damage and allows for rapid diffusion of oxygen into the tissue. Intact cells have reducing characteristics which mean that oxygen is reduced in a controlled way in respiration rather than taking part in browning reactions.
4. The piece in the air should brown fastest; the one in water should be next; the piece in ascorbic acid takes longer to brown and the sulphur dioxide piece takes much longer to brown. The one in air has greater contact with oxygen than the one in water. Ascorbic acid is a reducing agent and hence will slow down the rate of **oxidation**. Sulphur dioxide is a common preservative; in this case it is acting as an **enzyme** inhibitor.
5. The piece in boiling water should take a long time, if at all, to brown. If this was a purely chemical reaction, the rate of browning should increase with temperature. The result suggests an enzyme controlled reaction. This is enhanced by the fact that the piece at 30 ^{o}C should brown more quickly than others at room temperature.
6. Bruising should have a similar effect to pulping since bruising also causes extensive cell damage. Pupils may wonder how the reaction occurs without the air/oxygen seemingly being in contact with the tissues. It is important for them to realise that very little oxygen is needed to initiate oxidation. Dissolved oxygen will be present in the tissues and this is taking part in the reaction.

Two important points come from these tasks. The browning reaction is:

- enzyme controlled;
- an oxidation reaction.

Hence, the reaction may be prevented or slowed down by using methods which restrict enzyme action or methods which employ an antioxidant or reducing agent.

Further investigations

The suggestions for further investigation may be suitable for assessment of Sc1. Since pulped apple browns more quickly and evenly than whole pieces, it is advisable to use pulp in further investigations.

a. There are many other natural **antioxidants** that could be investigated.

KS4

science and food technology

Timing - 40 - 60 minutes

Pupil activity sheet AO1 accompanies this activity.

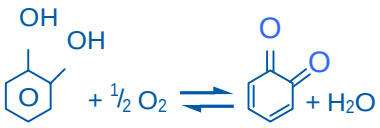
Requirements

- *apples (see below)*
- *knives or scalpels*
- *white tiles to cut on*
- *a blender or pestle and mortars*
- *5%ascorbic acid (Vitamin C) sol.*
- *sodium metabisulphite - to give a dilute solution of sulphur dioxide use 2 g in 100 cm^3 of water*
- *beaker of boiling water*
- *beaker of water at 30 ^{o}C*

***Apple selection** - you need to choose a variety which browns in the shortest time possible; cooking apples and continental apples brown more quickly than English eating apples; it is recommended that you try a particular apple first since even different batches of the same apple type will show variations.*

Cooks and chefs add lemon juice to prevent browning.

***For teacher information:** the browning reaction is really a series of reactions which result in the oxidation of compounds which contain the structure of 1,2-dihydroxybenzene. The first reaction in the sequence is catalysed by the enzyme polyphenoloxidase and this is the reaction that is important in the pupils' investigations. It is an oxidation reaction which produces a quinone.*



a quinone

There are many potential substrates for the reaction, but they are usually referred to as the 'tannins'. The final reactions are polymerisation reactions which produce the highly coloured pigments

You could try a number of acids - malic acid (E296), this is the principal acid in apples; citric acid (E330), the principal acid in citrus fruits; acetic acid (E260) which is vinegar.

b. A set of **buffers** could be used to produce a variety of pHs. Alternatively, mixtures of 0.4M disodium hydrogen orthophosphate and 0.2M citric acid solutions can be used.

0.4M disodium hydrogenorthophosphate/cm ^{3}	0.2M citric acid/cm ^{3}	pH (approx.)
0.4	19.6	2.2
4.1	15.9	3.0
7.7	12.3	4.0
10.3	9.7	5.0
12.6	7.4	6.0
16.5	3.5	7.0
19.4	0.6	8.0

c. Since this is an enzyme controlled reaction, a range of temperatures can be chosen to reflect knowledge of the effect of temperature on enzymes.

d. A range of suitable concentrations could be from 0 to 10% acid.

e. Different types of apples, i.e. different substrates, do brown at different rates. Dessert apples tend to brown more slowly than cooking apples. This is due to lower levels of tannin in dessert apples which have been selected for this reason over many years.

In all of these investigations, one of the most difficult aspects is the ability to measure the extent of the brown colour accurately.

OXYGEN - FRIEND OR FOE?

All life needs oxygen. It is used in all plant and animal cells in the process of **respiration**. This process releases the energy contained in the food we eat so that we can do things. Reactions between oxygen and another substance are called **oxidation** reactions.

But is oxygen always useful? Foods can also be attacked by oxygen. Food additives called **antioxidants** are used to try and slow down the reaction between food and oxygen. Antioxidants are numbered from E220 - E330 (you may find that some of the preservatives are found within these numbers too).

Foods which contain **fats** and oils, in small or large quantities, are particularly susceptible to oxidation. The softer fats are described as being **unsaturated**. These fats may be less likely to cause harm to our health than the saturated fats but they are more likely to be attacked by oxygen. When fats become oxidised they produce unpleasant and sometimes dangerous substances; the fats become **rancid**.

It is hard to believe, but pure oxygen can be dangerous to our health. It seems that oxidation reactions inside our bodies could lead to increased risk from heart disease. Our bodies have natural antioxidants (vitamins C and E are examples) and consuming these, and other antioxidants, through our diets, could prove to be very important in combating heart disease.

Other effects of oxidation are less dangerous but also undesirable. You are going to investigate a very common oxidation reaction.

Why has my apple gone brown?

You may have noticed when peeling and slicing fruits such as apples, that the fruit starts to change colour and goes brown with time. This is not a problem when eating a raw apple as a snack but it is of great importance in the large scale production of many fruit products.

Cooks and chefs, perhaps by chance, found a simple way of slowing down this browning reaction. Do you know what they did?

Carry out the following investigation which will allow you to find out more about this browning reaction. There are a number of small tasks to do. You may like to divide the work up between a few groups and then pool results.

If you are the group using boiling water or water at 30°C, get this ready before you cut your apple.

SAFETY - USE SAFETY GOGGLES WHEN HEATING
BE CAREFUL USING KNIFE or SCALPEL BLADES
ASTHMATICS MAY BE SENSITIVE TO SULPHUR DIOXIDE

Method

1. You will need 11 pieces of apple for the entire investigation. Each piece needs to be about an eighth of a typical eating apple.
2. Take 2 pieces of apple. Leave them both to brown. When they are brown cut one of them in half using a knife/scalpel. Break the other into two pieces using your hands. What happens to the freshly cut surface and the freshly broken surface?
3. Take 2 pieces of apple. Turn one of them into a pulp (using a blender or a pestle and mortar. Compare the browning of the pulp with the unpulped piece.
4. Take 4 pieces of apple. Put one in water. Put one in ascorbic acid solution. Put one in dilute sulphur dioxide solution. Remember that apples will float so you will need to find a way to keep them below the liquid surface. Leave the fourth piece in the air. Leave them all for a few minutes and then compare.
5. Take 2 pieces of apple. Drop one piece into a beaker of already boiling water. Leave in the water for 2 minutes. Transfer the piece to cold water for 1 minute. Remove it and then leave it in the air.

   Drop the second piece into a beaker of water at 30^{o}C for 2 minutes. Transfer the piece to cold water for 1 minute. Remove it and then leave it in the air.

   Compare the two pieces after a few minutes.
6. Take 1 piece of apple. It must still have the peel on. Bruise this piece, peel side down, by hitting it against a hard surface. Leave for a few minutes and then cut it open to see what has happened.

If different groups have done these tasks, you will have to get together to give each other the results. Using the results, write a few sentences about what each of the tasks tells you about the browning reaction in apples.

Further investigations

a. Investigate if other substances such as vanilla, other acids (instead of ascorbic acid), mustard, sesame seeds and rosemary can also slow down the browning reaction.

b. What effect does pH have on this reaction?

c. Investigate in greater detail the effect of temperature on this reaction.

d. What is the lowest concentration of ascorbic acid that can be used to significantly slow down the browning reaction?

e. Do different types of apples, e.g. Bramley, Golden Delicious, Cox, Granny Smith's, brown at different rates?