What affects the colour and texture of cooked vegetables?

Introduction

Heston Blumenthal is one of the top chefs in the country – his restaurant, The Fat Duck, has three Michelin stars. He is noted for his scientific approach to cooking – he regularly asks the question '***why?***' rather than accepting what other chefs say, and he devises and carries out experiments to try to find answers.

Heston Blumenthal in The Fat Duck

One question posed by Heston Blumenthal early in his career as a 'scientific chef' was '***Why do cooks add salt (sodium chloride) when cooking vegetables, for example green beans?***' Possible reasons suggested by cooks included:

- it keeps the beans green
- it raises the boiling point of water so the beans cook faster
- it prevents the beans going soggy
- it improves the flavour.

Some cooks add sodium bicarbonate (sodium hydrogencarbonate, also called bicarbonate of soda) when cooking green vegetables to maintain the colour. In The Fat Duck, a water softener is used because it is believed that the calcium ions in hard water affect the colour and texture of cooked vegetables.

What affects the colour and texture of cooked vegetables?

Practical work

Your task is to devise experiments that can test whether some of the suggestions above are correct. Bear in mind that your experiments must be fair tests and that you must only change one factor at a time if you are to be able to draw sensible conclusions from your results. As well as deciding what to do, you will also have to think about how you record your results.

Scientists do not often use tasting in their experiments so you must take great care with hygiene precautions, especially if you are working in a laboratory. Follow carefully all the precautions that your teacher explains to you.

What affects the colour and texture of cooked vegetables?

1. The effect of salt and of sodium hydrogencarbonate on the colour of vegetables

Devise and carry out experiments to investigate the effect on the colour of cooked vegetables of adding salt (sodium chloride) and sodium bicarbonate (sodium hydrogencarbonate) to the cooking water. There are many variables involved including concentration of additives, cooking time and type of vegetable. Peas or green beans are convenient to use because they can be cooked in small quantities and they have a relatively uniform colour. You will have to assess any colour changes with the naked eye and this will inevitably be subjective. Colour assessment could be made more objective by (a) using a tester who is not aware of how each sample has been treated and/or (b) using an 'odd one out' test. Here a tester is offered three samples to assess, one cooked in one way and two cooked in another, and asked to pick the odd one out.

Sodium hydrogencarbonate makes the cooking water slightly alkaline. As an extension activity, you could investigate the effect of cooking green vegetables in water to which a little vinegar has been added to make it acidic.

Apparatus and equipment

Your group will need:

- saucepan or large beaker in which to cook the vegetables
- spoon or large spatula to remove vegetables from boiling water
- access to a top pan balance
- access to a cooker or other means of boiling vegetables (*eg* Bunsen burner, tripod, gauze and heatproof mat)
- saucers (ideally white) or petri dishes on which to display samples for testing
- a tea strainer or similar would be useful for draining the vegetables.

Chemicals

Your group will need:

- sodium hydrogencarbonate
- sodium chloride (table salt)
- peas – fresh or frozen (or other green vegetables)
- vinegar (for the extension activity).

2. The effect of calcium ions on the texture of vegetables

You can investigate this by cooking dried peas that have been soaked overnight in (a) deionised water, (b) tap water, (c) 2% calcium chloride solution, (d) 4% calcium chloride solution. Drain the peas and then simmer them in a saucepan with a lid or beaker of water covered with a clock glass (to reduce evaporation) for 10 minutes. After this time taste a sample of peas to assess the texture. Continue the sampling and tasting at regular intervals and note the time taken for each type of pea to achieve an acceptable texture.

Apparatus and equipment

Your group will need:

- saucepan with lid or large beaker with clock glass in which to cook the vegetables
- spoon or large spatula to remove vegetables from boiling water
- access to a top pan balance
- access to a cooker or other means of boiling the vegetables (*eg* Bunsen burner, tripod, gauze and heatproof mat)
- saucers or petri dishes on which to display samples for testing
- a tea strainer or similar would be useful for draining the vegetables.

Chemicals

Each group will need:

- dried peas
- deionised water
- 2% calcium chloride solution
- 4% calcium chloride solution.

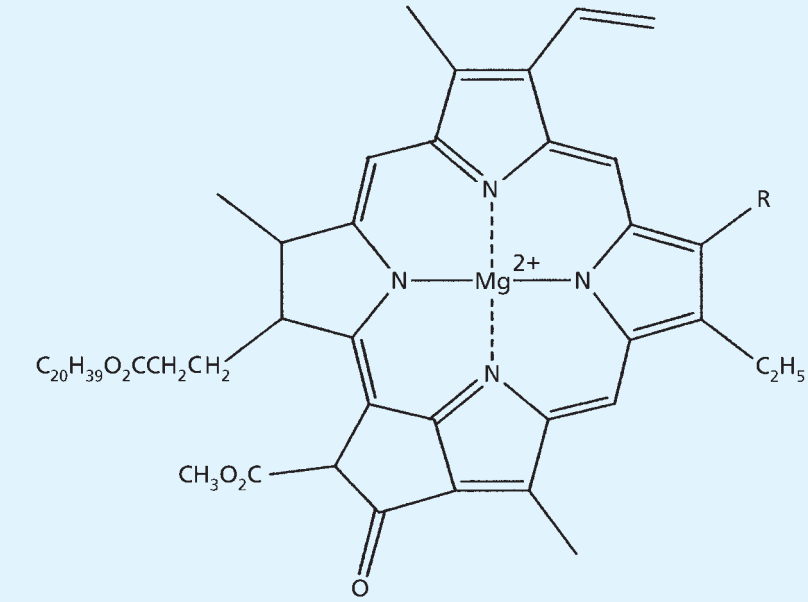
Safety

- Wear eye protection.
- Take care with boiling water.
- Make sure that you follow the hygiene precautions that your teacher explains to you.

3. What affects the colour of green vegetables during cooking?

Read the material below which explains some of the chemistry that underlies changes in colour and texture of food during cooking. Then answer the questions below.

The colour of green vegetables is largely due to chlorophyll.

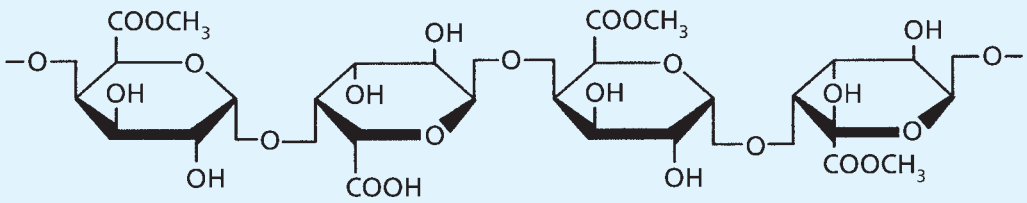


The chlorophyll molecule

Chlorophyll has a porphyrin ring system with an Mg^{2+} ion in its centre. During cooking this magnesium ion can be replaced by two H^+ ions to give a compound called phenophytin. This is olive green/brown and is responsible for the colour of overcooked vegetables. The replacement of Mg^{2+} by two H^+ ions takes place most readily in acidic conditions and this is the reason why some cooks add sodium hydrogencarbonate (everyday name sodium bicarbonate or bicarbonate of soda) when cooking vegetables. This keeps the cooking water alkaline and minimises replacement of magnesium ions thus maintaining the green colour. (Sodium hydrogencarbonate, $NaHCO_3$, is the salt of a strong alkali (sodium hydroxide) and a weak acid (carbonic acid) and is therefore alkaline.) Unfortunately, alkalis catalyse the oxidation of vitamin C (ascorbic acid) to dehydroascorbic acid. So, addition of sodium hydrogencarbonate is not ideal as it accelerates the loss of this vitamin. There appears to be no good reason why addition of salt would affect the colour of vegetables during cooking.

4. What affects the texture of green vegetables during cooking?

Pectins, which are polysaccharides, are present in vegetables, and form water-retaining gels that help to give vegetables their structure.



A section of a pectin molecule

During cooking, pectins become soluble and are extracted into the cooking water making the vegetable go mushy. Calcium ions, Ca^{2+}, found in hard water, can form cross links between pectin molecules making them less soluble and keeping the vegetable tough. In the Fat Duck restaurant, for example, the local water is relatively hard and the chefs began to cook vegetables in bottled water to reduce this effect and shorten cooking times. Now, one of the taps is fitted with a water softener to reduce the level of Ca^{2+} ions in the water.

The calcium ion content of water can affect the colour of cooked vegetables as well as their texture, but indirectly, by its effect on pectin molecules. Since most vegetables require some softening during cooking, cooking in hard water means that longer is needed to achieve the optimum softening. During this longer cooking time, more chlorophyll is converted to phenophytin and the colour of green vegetables becomes browner.

Questions

1. Look at the formula of a section of the pectin molecule. What will happen to some of the –COOH groups in water? How will this be affected by making the water more alkaline? Suggest how a Ca^{2+} ion could form a link between two pectin molecules. Is this link more likely to form in acidic or alkaline conditions?

2. Pectin forms water-retaining gels. Look at the formula of pectin. What features of the molecule allow it to bond with water molecules? What type of bonds are formed?

3. The pectin molecule contains –COOH groups. How will these react with sodium hydrogencarbonate? Write an equation for this reaction representing pectin as RCOOH. Would you expect the organic product of this reaction to be more or less soluble in water than pectin itself? Explain your answer. What would you predict to be the effect on the texture of vegetables of cooking them in water to which sodium hydrogencarbonate has been added?