

Chemical changes during cooking

Read the passage below and answer the questions.

Chemical changes during cooking

Why do we cook food? There are many reasons, including killing bacteria and other microorganisms in or on the food to make it safe to eat. Many of the other reasons are to do with increasing the **acceptability** of the food. This can include improving the texture (softening tough meat, for example), improving the colour (browning of meat or toast, for example) and improving the flavour and aroma (developing the flavour and aroma of cooked meat, for example). Sometimes there can be a conflict between these goals. Cooking vegetables may soften them and enhance the flavour but may also result in a loss of colour. So using appropriate cooking conditions, such as temperature and cooking time is important.

Cooking meat

Meat is cooked for a number of reasons which include:

- Browning of the outside – this improves the appearance and also produces flavour and aroma molecules. At temperatures of above 140°C a group of chemical reactions called the Maillard reactions occurs. These take place between carbohydrates and molecules with $-\text{NH}_2$ groups. They are a complex and incompletely understood set of reactions but the final products include polymers that make the meat brown and also volatile flavour molecules that give the aroma and taste of roast meat.
- Decomposing molecules of collagen that form the connective tissue of meat. Connective tissue is the thin translucent film that separates layers of muscle (see Figure 1). It holds muscles together and attaches muscle to bone. Too much of it makes the meat tough. Collagen is a protein in the form of a triple spiral rather like rope (See Figure 2). At temperatures above 60°C the spiral begins to unwind and the collagen softens, eventually turning into gelatine – a soft material that is a constituent of jellies.



Figure 1 Connective tissue in meat

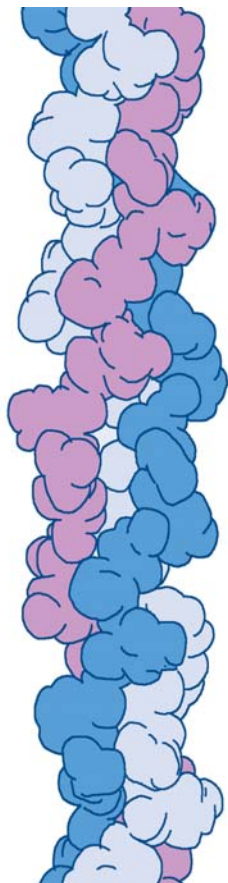


Figure 2
The rope-like structure of the collagen molecule

Other undesirable changes may take place during the cooking of meat - other protein molecules begin to change (denature) at about 40 °C and cause the meat to harden, for example.

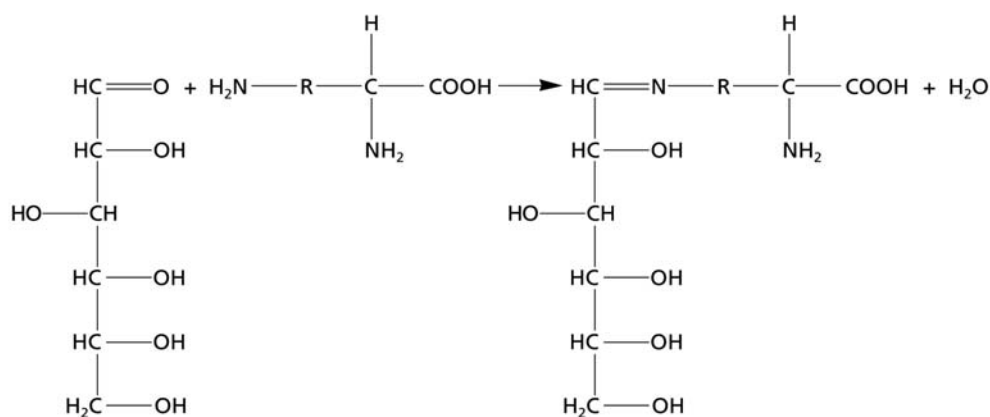
This means that there is no single 'right' temperature for cooking meat. Meat with a high collagen content (large amounts of connective tissue) will have to be cooked at above 60 °C to break down the collagen (below this temperature collagen hardly breaks down at all), while meat with little connective tissue would be better cooked at 50 °C or less to prevent hardening.

The Maillard reactions do not take place below 140 °C, which would be far too high a temperature for cooking. One way round this is for cooks to use a blow torch to heat the surface of the meat to over 140 °C for a few moments – enough for Maillard browning to occur on the surface but not long enough for this temperature to occur in the bulk of the meat.

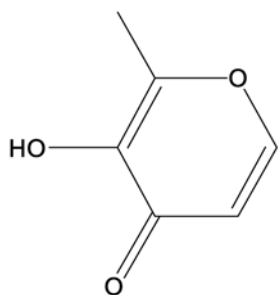
The size of the piece of meat is also important. Meat is a relatively poor conductor of heat so the temperature inside the meat will lag behind that of the surface. This is obvious when you carve a joint that has been roasted in the oven. The centre of the joint could be relatively raw and red while the surface is brown. Heston Blumenthal uses temperature probes like those used in data loggers to monitor the temperature inside joints of meat that are being cooked in his restaurant, The Fat Duck, to ensure that meat is at the optimum temperature. He cooks some cuts of meat sealed in plastic bags in a temperature-controlled water bath.

The Maillard reactions

These reactions, discovered by Louis-Camille Maillard in 1911, occur between sugars and amino acids. Because there are 20 different amino acids found in living things and several different sugars, it is better to describe them as a group of reactions rather than a single one. The variety of the starting materials also explains the complexity of the reactions and why they are still not fully understood almost a century after their discovery. They are further complicated by the fact that sugars exist in both ring and chain forms. The first step of the reactions occurs between the carbonyl group of a sugar molecule (in the chain form) and an –NH₂ group to eliminate a molecule of water. The –NH₂ group may be part of an amino acid molecule (that was originally part of a protein molecule) or an amino acid that is still part of a protein chain. In the latter case, it must be an amino acid that has an –NH₂ group as part of its side chain. This side chain is different for each amino acid and is represented by R – NH₂ in the reaction scheme below.



Further steps then follow. Over 1000 different molecules have been identified as products of the Maillard reactions. These include polymers that are responsible for the brown colour of roast meat (and toast, etc) and small molecules such as maltol that are responsible for aromas.



Maltol

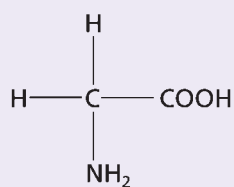


Uncooked meat (left).

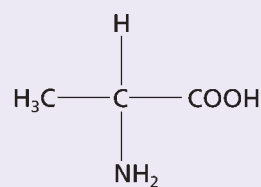
The Maillard reactions are evident in the appearance of the meat after cooking (right)

Questions

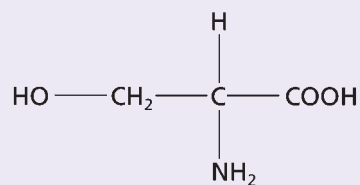
1. Which of the following amino acids could take part in the Maillard reactions when they form part of a protein chain? Explain your answer



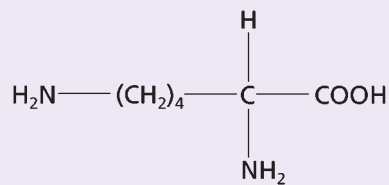
Glycine



Alanine



Serine



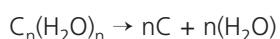
Lysine

- On a copy of the reaction scheme for the first step of the Maillard reaction (see page 2), draw the lone pair on the -NH_2 group and mark the $\delta+$ and $\delta-$ areas on the C=O group of the sugar. Hence suggest what the first step of the mechanism of this reaction is likely to be.
- The Maillard reaction scheme above shows the chain form of glucose. In solution, the majority of glucose molecules exist in the form of a ring. Draw the ring form of glucose. Classify the type of reaction by which the chain form is converted into the ring form.
- Why is it unlikely that a polymer molecule would be responsible for an aroma?

Other types of browning

Caramelisation

Caramelisation is the name for the browning that takes place when sugar is heated – this is how toffee is made. On heating, sugar molecules first melt and then begin to dehydrate. The dehydrated molecules then begin to polymerise into brown-coloured polymers which have bitter tastes. Further heating will result in complete decomposition of the sugars, general formula $\text{C}_n(\text{H}_2\text{O})_n$, to carbon and water (in the form of steam):



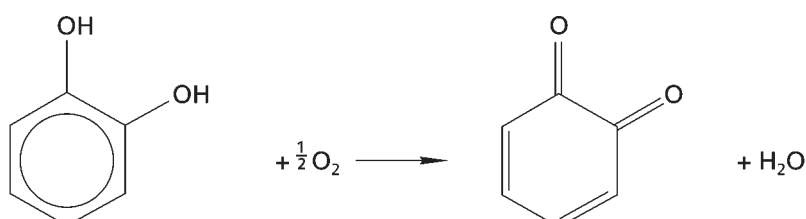
This reaction differs from the Maillard reaction in that proteins and amino acids are not involved.



Sugar before (left) and during (right) caramelisation in a pan

Enzymic browning

Enzymic browning is responsible for the browning of fruit such as apples and bananas once they have been cut or bruised. Unlike caramelisation and Maillard browning, it is not usually considered to improve the food because the browned fruit is thought to be unattractive in appearance and the reaction does not result in any aroma molecules. This browning is caused by the oxidation of compounds related to phenols (hydroxybenzenes) that are found inside plant cells. The oxidation occurs when the cells are damaged by cutting or bruising and become exposed to oxygen in the air and enzymes that catalyse the oxidation. The first step of the reaction is typically:



The product molecule then polymerises to form the brown pigment.



Apples before (left) and during (right) enzymic browning

Questions

5. (a) Name the functional groups in (i) the starting material and (ii) the product of the reaction above.

(b) Suggest two simple chemical tests that would enable you to distinguish between the starting material and the product in the reaction shown on page 4. In each case say what you would do and what result you would expect for both starting material and product.

6. (a) Cooks normally want to prevent or slow down the browning reaction. One way of doing this is to add vitamin C to the fruit. Vitamin C is a reducing agent and reacts with oxygen thus preventing oxidation reactions from occurring. There are several other possible methods including:

Blanching the fruit (immersing it in boiling water for a short time).

Adding an acid (such as lemon juice, which contains citric acid).

Storing the fruit under water.

Suggest how each of the methods above works to reduce the browning reaction.

(b) Suggest what restrictions there are on methods used to control the browning reaction if the fruit is to be used in cooking.