Nuffield Advanced Chemistry Special Study
FOOD SCIENCE
Teachers' and Technicians' guide

Contents

This teachers' and techicians' guide includes an introduction to the Special Study and details about each chapter.

For every chapter there is an introduction stating the objectives and giving a recommended timing for that chapter, together with background information. Each chapter concludes with a summary of the ideas covered.

Detailed information about the experiments for technicians and teachers is given on separate sheets.

ISBN 0 904956 30 X

Nuffield Advanced Chemistry Co-ordinator: Alan Furse

Author: Kamil Aliss Contributors: J.M.V. Blanchard, C.J. Brock, and David Craggs
Safety adviser: Peter Borrows

First published by Longman in 1971 This edition downloaded from www.nuffieldchemistry.org

Drawings by Hugh Neill and Oxford Illustrators Limited; structure diagrams by Speedlith Limited

ISBN 0 904956 30 X

Health and Safety

See the safety notes given with each experiment.

Health and safety in school and college science affects all concerned: teachers and technicians, their employers, students, their parents or guardians, as well as authors and publishers.

As part of the reviewing process, these publications have been checked for health and safety. In particular, we have attempted to ensure that:

- all recognized hazards have been identified,
- suitable precautions are suggested,
- where possible, the procedures are in accordance with commonly adopted model (general) risk assessments,
- if a special risk assessment is likely to be necessary this has been pointed out
- where model (general) risk assessments are not available, we have done our best to judge the procedures to be satisfactory and of an equivalent standard.

It is assumed that:

- practical work is conducted in a properly equipped and maintained laboratory,
- rules for student behaviour are strictly enforced,
- mains-operated equipment is regularly inspected, properly maintained and appropriate records are kept,
- care is taken with normal laboratory operations such as heating substances and handling heavy objects,
- good laboratory practice is observed when chemicals are handled,
- eye protection is worn whenever the risk assessment requires it,
- any fume cupboard required operates at least to the standard of Building Bulletin 88,
- students are taught safe techniques for such activities as heating chemicals, smelling them, or pouring from bottles,
- hand-washing facilities are readily available in the laboratory.

Under the COSSH and Management of Health and Safety at Work regulations, employers are responsible for carrying out risk assessments before hazardous procedures are undertaken or hazardous chemicals used or made. Teachers are required to co-operate with their employers by complying with such risk assessments.

However, teachers should be aware that mistakes can be made and, in any case, different employers adopt different standards. Therefore, before carrying out any practical activity, teachers should always check that what they are proposing is compatible with their employer's risk assessments and does not need modification for their particular circumstances. Any local rules issued by the employer must always be followed, whatever is recommended here.

Model (general) risk assessments have been taken from, or are compatible with:
CLEAPSS *Hazcards* 1995 or later
CLEAPSS *Laboratory handbook* 2001 or later (paper or CD-ROM versions)
CLEAPSS *Recipe cards* 1999 or later
Association for Science Education *Safeguards in the school laboratory* 10th edition 1996
Association for Science Education *Topics in Safety* 3rd edition, 2001

Clearly, you must follow whatever procedures for risk assessment your employers have laid down. As far as we know, all the practical work and demonstrations in this course are covered by the model (general) risk assessments detailed in the above publications, and so, in most schools and colleges, you will not need to take further action.

If you or your students decide to try some procedure with hazardous substances beyond what is in this course, and you cannot find it in these or other model (general) assessments, then your employer will have to make a special risk assessment. If your employer is a member, then CLEAPSS will act for them. Otherwise the ASE may be able to help.

Only you can know when your school or college needs a special risk assessment. But thereafter, the responsibility for taking all the steps demanded by the regulations lies with your employer.

Investigations will involve independent action by the student. Our notes on investigations warn students to carry out a risk assessment; students should be responsible for safety in the first instance and credited in any assessment for making safe plans. Nevertheless, proposals must be seen by you the teacher and you must ensure that you make an appropriate check, particularly with respect to safety, on what will go on. You will need to take particular care if students consult library books published before modern safety standards came into force or get ideas from the internet.

INTRODUCTION FOOD SCIENCE

This *Food science* Special Study is for students interested in the application of science, especially chemistry, to food and feeding problems. It is also for all students interested in food, and particularly in food science and technology as a career.

Food science is the application of physical and biological sciences to the processing, preservation, storage, and distribution of food, and the development of new and improved food products. The growth in the world population, combined with urbanization and an increased demand for different foods due to affluence, has dramatically increased the complexity of the feeding problems, and the need for food technologists.

Contents and timing

Chapter 1	Introducing food science	homework
Chapter 2	The nutrients in food	1 week
Chapter 3	The quality of food	1/2 week
Chapter 4	Microbial and biochemical changes in food	1 week
Chapter 5	Food preservation	homework
Chapter 6	Cereal science	1 week
Chapter 7	Food legislation	homework
Chapter 8	The hungry World	homework
Discussion of homework:		allow 1/2 week

The Special Study occupies about four weeks, assuming about 4.5 hours of contact time per week. The practical work is mainly to be found in Chapters 2, 4 and 6. The chapters that can be read for homework will need discussion time in class.

Aims

1 To introduce students to the chemical aspects of food science, and to explain the nature of food.

2 To illustrate the application of physical and biological sciences to the processing, preservation, and storage of food, and the development of new and improved food products.

3 To provide experimental work to illustrate how chemistry is applied to food science.

4 To introduce students to some of the legal and moral issues raised by food.

CHAPTER 1 INTRODUCING FOOD SCIENCE

Content

1.1 Science and food
1.2 The nature of food

Timing

One hour.

Students should read Chapter 1 for homework. Any questions may then be discussed for a short time during the first lesson.

Objectives

1 To encourage the students to think about the need to produce and to use food more effectively.
2 To outline the nature of food, and the need for a balanced diet in terms of nutrients.

Commentary

This is an introductory chapter but contains important ideas which the students need to take note of: the six types of essential nutrients, their three basic functions, and our energy requirements.

Interest in food science can be heightened, and its relevance illustrated, by establishing a 'bulletin board' where current newspaper and magazine cuttings can be displayed. The web links on www.chemistry-react.org may also help.

Summary

At the end of this chapter students should:
1 know that food science is the study of the properties, preservation, and processing of food
2 recall the six essential nutrients, carbohydrates, fats, proteins, mineral elements, water, vitamins
3 recall the functions of nutrients: to build and maintain the structure of the body, to provide energy for movement and warmth, and to produce energy and chemicals to maintain the chemical reactions taking place.

CHAPTER 2 THE NUTRIENTS IN FOOD

Content	Timing
2.1 Fats	One week
2.2 Proteins	
2.3 Carbohydrates	
2.4 Vitamins	
2.5 Minerals	
2.6 Water	
2.7 Investigating the composition of foods	

Experiment 2.7a Investigating the glucose content of drinks
Experiment 2.7b Investigating the effect of cooking on the vitamin C content of cabbage

Objectives

1 To review the chemical nature and functions of the nutrients in food.
2 To introduce experimental methods for investigating nutrients.
3 To investigate one example of the effect of cooking on the nutritional value of food.

Commentary

The sections on fat, carbohydrates, and proteins assume that the students are familiar with Topic 14 in the main course dealing with these compounds.

Students should read the theoretical introduction for homework. Any questions can then be discussed at the start of the lesson, and experiments carried out during the remainder of the lesson.

2.1 Fats

Depending on the original source, oils and fats may be designated as vegetable or animal fats. The chief physical difference between an oil and a fat is that at 20 °C most vegetable oils are liquid. The exceptions are palm kernel and coconut oil, which soften/melt above this temperature. A fat is solid at 20 °C. All oils and fats contain a proportion of combined unsaturated fatty acid, and this proportion is greater in the case of oils. The degree of unsaturation is measured by the oil's *iodine value*. When iodine (in practice iodine monochloride or iodine trichloride) is added to a triglyceride containing an unsaturated fatty acid, the iodine adds across the double bond. The degree of unsaturation may be calculated from the amount of iodine reacting. The iodine value is defined as the number of grams of iodine needed to saturate 100 grams of oil. The iodine value may be used to identify oils and fats. See the table opposite.

Iodine values of fats and oils

Fat/oil	Iodine value /g per 100 g of oil
Waxes	very low
Animal fat	
Butter	25–30
Lard	45–65
Dripping	35–65
Vegetable oil	
Olive oil	80–90
Almond oil	90–110
Ground-nut oil	85–105
Cotton seed oil	80–140
Soya oil	80–140

Although the iodine value of an oil is constant, the exact figure obtained will depend on the particular technique used.

2.2 Proteins

Students are referred to Topic 18. The information on the structure of proteins and enzymes in Topic 18 should be regarded as an examinable part of this Special Study. Students should be able to apply their knowledge of enzymes in the context of food science.

2.3 Carbohydrates

There is now no introduction to carbohydrate chemistry in the main 4th edition *Students' book*.

2.4 Vitamins

Vitamin C is present in a variety of fruits and vegetables. Unlike most vitamins, vitamin C is readily destroyed during processing and storage. In addition to the reference in the *Students' book* to Scott's expedition to the South Pole teachers may like to refer to the problem of scurvy that afflicted sailors on early long voyages. On Drake's voyage round the world his seamen ate on their food the powdered bark of a tree rich in vitamin C. A specimen of the tree, *Drimys winteri*, can be seen in Heligon Garden, Cornwall together with a notice telling the story.

Vitamin C content of a variety of vegetables and fruit

Vegetable or fruit	Vitamin C /mg per 100 g
Brussels sprouts	87
Cabbage	53
Cauliflower	64
Potatoes	8–30
Lettuce	15
Orange	50
Lemon	50

Deterioration of vitamin C is increased in the following ways:

- In alkaline conditions (pH > 6.8) vitamin C deteriorates rapidly. Adding sodium hydrogencarbonate during cooking, although preserving the colour of vegetables, is nutritionally undesirable because almost all the vitamin C is destroyed. On the other hand, it is relatively stable in acid conditions.
- By rapid oxidation on exposure to air. The enzyme ascorbic acid oxidase, which is present in fruits and vegetables, is released by any physical damage, and this increases the rate of oxidation of vitamin C.

2.7 Investigating the composition of foods

Experiment 2.7a Investigating the glucose content of drinks

Experiment 2.7b Investigating the effect of cooking on the vitamin C content of cabbage

See separate teachers' and technicians' notes. These experiments can be carried out at any convenient time during the teaching of 'Food science'.

Summary

At the end of this chapter students should:

1 have knowledge of the structure and chemical nature of the nutrients in food, and the role they play in energy production, tissue building and regulating body processes

2 recall experimental procedures used for the quantitative determination of the glucose and the vitamin C content of foods

3 know and understand some recommended methods for processing and cooking vegetables so as to prevent the destruction, or loss, of vitamin C.

CHAPTER 3 THE QUALITY OF FOOD

Content

3.1 Eating qualities
3.2 Water-holding capacity
3.3 Texture in foods of plant origin
3.4 Texture in foods of animal origin
3.5 Flavour and colour
3.6 Genetic engineering
3.7 Investigating texture and taste

Experiment 3.7a The effect of calcium ions on the texture and flavour of peas
Experiment 3.7b Taste
Experiment 3.7c The tongue and the primary taste sensations

Timing

1/2 week.

Objectives

1 To discuss food in terms of its eating qualities.
2 To show how the eating quality depends on the structural and the chemical characteristics of the food's ingredients.

Commentary

One of the important points to discuss is acceptability of food. The majority of people would eat most things if they had to. The acceptability of a material as a food varies with circumstances. In times of famine, or lost in the Andes, people would consider eating anything in sight – rats, old boots, and even each other.

In affluent areas, where there is plenty of food, the consumer is much more particular. In a land of plenty a material must not only be nutritional but it must also have good eating qualities. It must:

- have a pleasant colour, smell, taste, and texture; a food must have all the characteristic properties we expect it to have; for example, an apple must be green, red or yellow, it must be crisp, and it must have the characteristic taste and smell
- not have unpleasant associations, as with snake, cat, rat, etc.

The various eating qualities may be discussed. Teachers should point out to the students that most of these qualities are subjective, some more than others. Whether a food has a good or an unpleasant flavour is a matter of opinion and may differ from country to country, and between different areas within a country. For example, seaweed is considered to be a delicacy in the West country and parts of Wales, but is considered less palatable in other parts of the UK.

Flavour and palatability

Flavour and palatability are subjective, and difficult to express, and people generally confine themselves to eating the type of food to which they are accustomed. New flavours and tastes are often accepted reluctantly and cautiously, but foreign travel has greatly widened the range of foods we find acceptable.

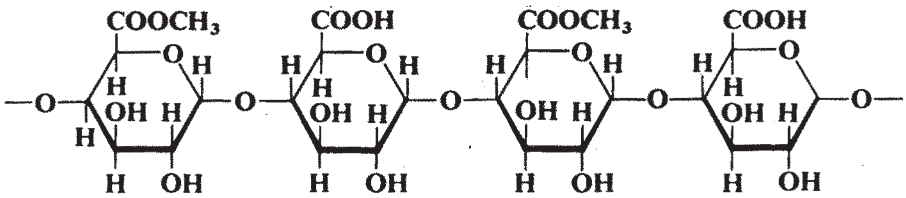
Colour

The colour of a food is important in determining whether or not we consider it to be edible. We are reluctant to eat foods which look unpleasant or have an unusual colour. Colours in food have a biochemical importance quite unconnected with the shaping of our attitude towards that food. Chlorophyll is green, not because we expect our vegetables to be green, but because plants need to absorb energy from the blue and red regions of the electromagnetic spectrum, to provide energy for the biochemical processes taking place in the plant cells.

Texture

Discussions of texture must take into consideration the structure of the material and its water-holding capacity. Why are fresh strawberries more pleasant than soggy ones? As consumers we prefer our foods to be firm and crisp. Both these qualities are governed by the cellular structure and water-holding capacity of the material. Freezing, followed by thawing and cooking, affects both the cellular structure and the water-holding capacity of a food.

The characteristic texture of fruits and vegetables is due to their pectin, which is found in the intercellular tissues. It is a polysaccharide consisting of units of methyl esters of galacturonic acid (see the structure diagram below).



Pectin

The firmness of cooked and processed vegetables is strongly influenced by the amount of calcium ions, the ratio of calcium to sodium, and the amount of calcium chelating compounds, such as phytin, which competes with pectin for the calcium ions. In general high calcium ion content, high calcium to sodium ratio, and low phytin content lead to a firmer product. This principle is sometimes used to control the firmness of vegetables. Soaking in a solution of calcium ions increases firmness. Soaking in a solution of sodium ions softens the product.

In the food industry, vegetables such as peas, potatoes, and tomatoes may be toughened by dipping in a solution of calcium ions, or by adding calcium ions before canning and cooking. Potatoes which break down on cooking are strengthened by this process. However, if the calcium ion concentration is too high, or the soaking is carried out for too long, the product will tend to become too tough, have a bitter flavour, and perhaps be bleached.

3.6 Genetic engineering

The application of genetic engineering to the production of transgenic plants and animals is a rapidly developing field so there should be topical examples to add to the examples in the *Students' book*. The web links on www.chemistry-react.org may help here. It is not expected that students should learn any of the experimental procedures of genetic engineering, but they should understand what is achieved so that they can take part in informed debate on the social issues involved.

3.7 Investigating texture and taste

⚠ HAZARD It is contrary to COSHH regulations to eat or drink in any laboratory which could be contaminated with hazardous chemicals. These tasting experiments must therefore be conducted in a food technology room or another room where eating is permitted.

When food is being used in experiments, the temptation for the students to sample it or to finish off unused portions is very great. The dangers of eating any food in a chemistry laboratory are very obvious. An additional hazard in food experiments is for a treated sample to be mistaken for an unused sample.

It is most important to impose a rule that, except for properly organized tasting experiments, nothing should be eaten during this Special Study, and none of the material should be taken from the laboratory or tasting sessions.

It is also important to ensure that all material which has been used in the experiments be gathered together at the end of the period and, if finished with, taken to a dustbin. This avoids the possibility of it being eaten by students from other classes or by a cleaner.

Experiment 3.7a The effect of calcium ions on the texture and flavour of peas

Experiment 3.7b Taste

Experiment 3.7c The tongue and the primary taste sensations

(See separate teachers' and technicians' notes.)

Summary

At the end of this chapter the students should:

1 appreciate that, in addition to providing the body with nutrients, food must be digestible (readily assimilated in the body) and palatable (pleasant to eat)

2 understand how the structural character of food is determined by its water-holding capacity, texture, tenderness, and juiciness

3 understand how the chemical character is related to taste, odour, and colour.

CHAPTER 4

MICROBIAL AND BIOCHEMICAL CHANGES IN FOOD

Content

4.1 Types of change
4.2 Microbial changes
4.3 Micro-organisms and food poisoning
4.4 Microbial changes in milk
4.5 Non-microbial changes

4.6 Investigating browning reactions in fruit and vegetables
Experiment 4.6a Which substances are involved in the browning reaction?
Experiment 4.6b When does the browning reaction take place?
Experiment 4.6c Is the reaction due to micro-organisms?
Experiment 4.6d Does the reaction require air or some part of the air?
Experiment 4.6e Can ascorbic acid be used to control the browning reaction?
Experiment 4.6f Controlling browning by inactivating the enzyme

4.7 Changing milk with enzymes
Experiment 4.7a Making curd from milk
Experiment 4.7b Making whey syrup using an immobilized enzyme

Timing

One week.

Objectives

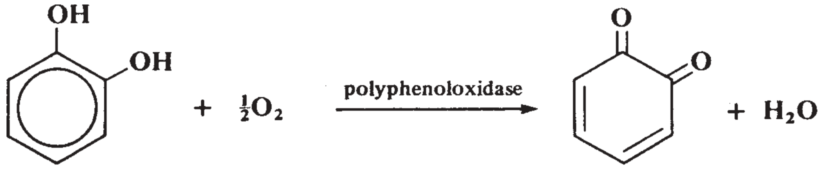
1 To introduce the micro-organisms which can change food, to describe the conditions under which they flourish, and to give an account of beneficial and harmful microbial changes, especially in milk.
2 To describe the conditions under which food poisoning may occur.
3 To give a brief account of some beneficial and harmful changes in food resulting from enzyme activity.
4 To carry out an experimental investigation of the chemistry of one reaction involving the spoilage of foods.
5 To carry out experiments involving some genetically engineered enzymes.

Commentary

Food is unstable, both as a raw material and as a processed product. Chemical reactions are occurring at varying rates, which affect the eating qualities and the nutritional value of a food.

Fruit-browning reactions are chosen for experimental investigation because they are relatively simple and safe, when compared with many more complicated kinds of food spoilage, such as fat oxidation and maturation of meat. However, the same principles apply. First it is essential to understand the chemical changes taking place and then to use this knowledge to devise methods of controlling the reaction.

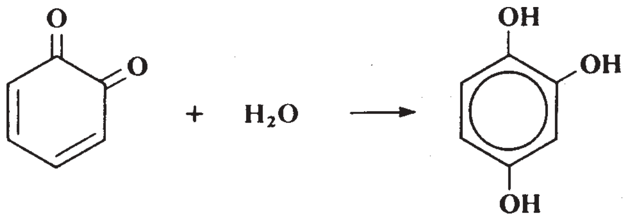
The browning in apples and potatoes is due to the enzymic oxidation of polyphenolic compounds, via quinones, into brown pigments. The reaction taking place can best be illustrated by reference to benzene-1,2-diol, although this is not a naturally occurring substrate.



benzene-1,2-diol (catechol) — cyclohexadiene-1,2-dione (a quinone)

The first stage in browning is an enzyme-catalysed oxidation of benzene-1,2-diol to a quinone.

In the second state the quinone reacts with water to form benzene-1,2,4-triol.

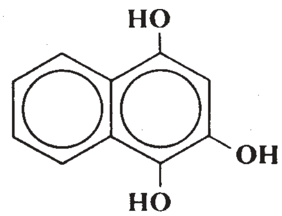


benzene-1,2,4-triol

Benzene-1,2,4-triol then reacts with any unchanged quinone, followed by a rearrangement to form a dicyclic compound.

This then polymerizes further to give highly coloured pigments of unknown structure.

The students need only know that the browning in fruits is due to enzymic oxidation of benzene-1,2-diol compounds to a quinone.



Furthermore, this information should only be given after they have established experimentally that the browning in apples or potatoes is due to an enzymic oxidation of benzene-1,2-diol compounds. It is essential that students should understand the importance of knowing as much as possible about the deterioration.

It should also be stressed that the control of the browning reaction is not just of academic interest, but is of importance in the processing of various fruit products.

4.6 Investigating browning reactions in fruit and vegetables

Once started, the students can work at their own rate through the experiments. (See the details on separate sheets.) The teacher should ensure that enough correct information is extracted from each experiment.

Experiment 4.6a is carried out first to establish that discolouration is due to substrates such as benzene-1,2-diol and benzene-1,2,3-triol. This is so that benzene-1,2-diol can be added to the samples in the subsequent experiments to intensify the colour and to accelerate the rate of browning.

Experiment 4.6a Which substances are involved in the browning reaction?

Experiment 4.6b When does the browning reaction take place?

Experiment 4.6c Is the reaction due to micro-organisms?

Experiment 4.6d Does the reaction require air or some part of the air?

Controlling the browning reaction

The reaction can be controlled in three main ways:

1 Reducing the concentration of the substrate by selecting apples or potatoes which have a relatively low substrate content. In the long term, manufacturers of fruit products might consider cultivating or genetically engineering plants to produce a variety with a very low substrate tannin content. A tannin-free variety of peaches has been cultivated.

2 Excluding oxygen or adding an antioxidant (Experiment 4.6e).

3 Inactivating the enzyme by:
i heating
ii adjusting pH to reduce activity (Experiment 4.6e)
iii adding chemical inhibitors (Experiment 4.6f)
iv altering the concentration of the reaction solution (Experiment 4.6f).

Experiment 4.6e Can ascorbic acid be used to control the browning reaction?

Experiment 4.6f Controlling browning by inactivating the enzyme

(See the separate teachers' and technicians' notes)

4.7 Changing milk with enzymes

In **Experiment 4.7a** and **4.7b**, students make curd from milk, and make whey syrup using an immobilised enzyme. Details are given in the students' book.

Summary

At the end of this chapter students should:

1 know that bacteria, yeasts and moulds cause changes in food which may be beneficial or harmful

2 understand that the temperature, pH, humidity and oxygen supply can all affect the rate of growth of micro-organisms

3 know that, as well as spoilage organisms, there are pathogens which cause food poisoning either by infection or by releasing toxins into food

4 understand the types of microbial change which can occur in milk

5 know that biochemical reactions can cause beneficial and harmful changes in food

6 understand methods of investigating the browning reaction of fruit

7 know about the aims of genetic engineering.

CHAPTER 5 FOOD PRESERVATION

Content

5.1 Methods of preservation

5.2 Methods which destroy or inactivate micro-organisms and enzymes

5.3 Methods which create conditions that limit deterioration

Timing

Homework plus time for discussion.

Objectives

1 To show that the purpose of food processing is to reduce deterioration in quality and to increase the shelf-life of the food.

2 To discuss preservation techniques used to reduce or inhibit deterioration in food.

Commentary

The effectiveness of the various techniques is limited by the effect the processing has on the food. Processing is seldom wholly beneficial. Here are some examples.

- Heating may produce a cooked effect which affects the colour, texture, flavour and nutritional value.
- Irradiation may produce 'off' flavours and destroy vitamins, but it does not increase the radioactivity of the food.
- Chemicals may affect the texture and flavour of food.
- Freezing may affect the water-holding capacity of food, and hence its texture, and denature proteins.
- Dehydration may cause heat damage similar to cooking, irreversible loss of structure, denaturation of proteins and discolouration.
- Gene technology can create modified micro-organisms for food processing and transgenic plants with desired characteristics, but there are problems of public acceptability.

The skill in food processing lies in effectively increasing the shelf-life of the food with minimum changes in the characteristics of the food, that is to say, in producing a material which is just as palatable and nutritional as the original, without raising the cost of the product too much.

5.3 Methods which create conditions that limit deterioration

Figure 5.4 in the *Students' book* shows the different levels of *gross* tissue disruption resulting from three freezing regimes: immersion freezing at about –60 °C, freezing in a commercial blast freezer operating at –30 °C, and allowing to freeze in a chest freezer at –25 °C. In terms of gross intercellular cavity sizes the relationship between these three regimes is: slow freezing > blast freezing > cryogenic freezing ≈ native state.

However, the total amount of tissue destruction may actually be greater with blast freezing than with slow freezing. The conventional explanation for this is that when freezing takes place slowly, water has more opportunity to migrate to an existing ice crystal, and consequently the generation of further ice nuclei is discouraged. The result is that fewer, but larger ice crystals are present than would have been present had the cooling rate been faster.

In the case of cryogenic freezing, water has no time to migrate and so it freezes intercellularly. The cells show little plasmolysis and no extracellular ice formation. The result is an absence of damage at the gross tissue level, but extensive damage at the cytoplasmic level. While this may have no effect on gross texture, it can lead to disastrous off-flavour development in an unbalanced sample.

Summary

At the end of this chapter students should:

1 understand that food processing is designed to reduce deterioration in food while retaining palatability and flavour

2 understand how the methods employed destroy or inactivate some or all of the micro-organisms and/or enzymes in the food

3 recall methods of food preservation including heat processing, irradiation, chemical treatment, high pressure, freezing, dehydration and packaging.

CHAPTER 6 CEREAL SCIENCE

Content

6.1 Wheat grain
6.2 Moisture content
6.3 Protein content
6.4 Starch
6.5 Processing wheat to make flour
6.6 Bread making
6.7 Investigating flour
Experiment 6.7a The SDS sedimentation test for gluten (or optional gluten extraction)
Experiment 6.7b Gelatinization temperature of starch
Experiment 6.7c Comparison of flour colour and qualitative tests for flour improvers

Timing

One week.

Objectives

1 To introduce students to the nature of wheat, flour and bread.
2 To study in some detail the nutrients in flour and flour additives.

Commentary

To appreciate this chapter, all students should have first-hand experience of making bread. Some will have made bread at home, others will have done so in food technology or in junior science lessons in school. Even so, all could be asked to make some bread rolls at home and to bring samples to school for the first lesson on this chapter.

The miller, by blending together different flour streams, can produce a variety of flours, all having different uses (see the table below).

Product	Protein level	Type of wheat	Flour colour
Cake	medium or 10%	soft – low level of starch damage	fine white
Biscuit	low, 8–9%, producing a non-elastic product	soft – low level of starch damage	not important
Pastry			
a flaky	high, 10–12%	soft	not important
b short	low, 6–8%	soft	not important
Household flour	medium, 10%	soft	white
Standard bread	high, 11–14%	hard – high starch damage	white
Brown bread	high, 11–14%	hard – high starch damage	white flour streams blended with the bran streams
Wholemeal	high, 11–14%	hard	all the streams: bran, germ and white blended

Wheat will pass through many hands, and will go through many processes, before it reaches the consumer. At every stage the handler will be interested in various aspects of quality.

• The farmer will be interested in the yield, suitability for storing, and the price obtained for the crop.

• The miller will be interested in the amount of flour of the right quality that can be extracted from the grain, the ease of extraction, and the suitability of the flour to meet the needs of the baker.

• The baker will be interested in the quality of the flour, and whether it is suitable for producing specific baked products such as bread, cakes, biscuits and pastry.

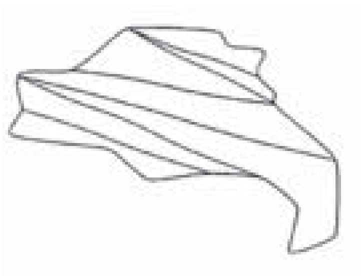
• Finally, and most important, are the interests of the consumer which are centred around taste, aroma, texture, safety, and cost of the products. It is the consumer who determines what the baker will produce, which will determine the type of grain the miller will produce, which eventually determines the varieties of crop sown and the treatment of the crop by the farmer.

With so many interested groups it is inevitable that wheat quality will be judged on many different factors. The criteria which are most important to the miller are:

• **ease of milling**

• **suitability** of the milled product for its eventual use.

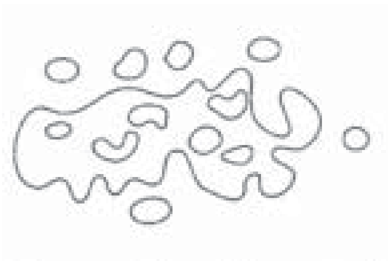
Ease of milling is affected by
- purity
- quality of the grain
- moisture content of the grain.



Sharp angular hard wheat flour particles flow easily without blocking sieves.

Sample purity is usually assessed visually. It gives the buyer an indication of the problems and costs involved in separating the wheat from the non-wheat material.

Grain quality is determined by carrying out tests on the ease with which the endosperm (flour) is separated from the bran. In *hard* grain the starch and protein in the endosperm are strongly bound together. On milling, the endosperm particles are not easily crushed; they form uniform free-flowing granules which are easily separated by sieving. In contrast, *soft* wheats produce particles having irregular shapes and sizes which are not free-flowing and are difficult to separate by sieving. Furthermore, hard wheat offers a greater resistance to the rollers and gives rise to starch damage. Damaged starch has a greater capacity to absorb water. This increases the water-carrying capacity of the dough, which is highly desirable in bread-making.



Unstructured loose soft wheat particles do not flow easily and block sieves.

Moisture content is important both to the farmer and the miller. It is important to the farmer because a moisture content that is too high will reduce the value and also affect the safe storage of the grain. It is important to the miller because a correct moisture level ($\approx$ 15%) limits the breaking up of the bran and improves the separation from the endosperm. Since it is easier to add water to produce the required moisture content, the miller prefers to buy wheat having a moisture content less than 15%.

Furthermore, a high moisture content in the grain can cause germination leading to a rapid increase in the level of α-amylase. α-amylase is an enzyme which is involved in breaking down the starch granules into sugars. A high α-amylase level in the flour produces a sticky product which is difficult to slice.

6.7 Investigating flour

Experiment 6.7a The SDS sedimentation test for gluten

Optional variant on Experiment 6.7a: Extracting gluten from flour
(student instructions are provided with the teachers' and technicians' notes on the experiment)

Experiment 6.7b Gelatinization temperature of starch

(See the teachers' and technicians' notes supplied separately.)

Summary

At the end of this chapter students should:

1 recall the composition and structure of wheat

2 understand the changes that can occur when wheat is processed to make flour

3 recall the changes that occur during baking

4 understand the methods used to investigate the composition of processed flour.

CHAPTER 7

FOOD LEGISLATION

Content

7.1 The need for food legislation
7.2 Food Safety Act 1990
7.3 Continuing regulation
7.4 Investigating labelling

Timing

This chapter may be set as homework, with a brief discussion in class.

Objectives

1 To show how the public is protected by legislation.
2 To illustrate by examples how the enforcement procedures operate.

Commentary

Food legislation is necessary to:

- prevent adulteration and contamination of food and food sources
- to prevent the sale of low-quality food
- to establish and maintain compositional and nutritional standards
- to prevent the use of non-beneficial additives
- to prevent misleading labelling and to promote informative labelling.

The generally applicable food legislation that was enacted in 1860 was designed primarily to prevent adulteration of foodstuffs and harm to the consumer. Food legislation has developed since the mid-nineteenth century and the modern legislation continues to reflect many of the basic principles established at that time. The main function of modern food legislation is to establish and maintain standards for the composition of food, to control the use of additives, to prevent misleading labelling and to promote informative labelling.

Food legislation was given a new impetus by the Food Safety Act 1990. That impetus was prompted largely by technological and social changes that had radically altered food production, retailing practices and consumer behaviour and by the need to ensure that the United Kingdom is able to comply with the requirements of European Union Law, which is playing an increasing role in food safety and regulation.

Framework legislation is provided by the Food Safety Act 1990 and later updates. However, much of the detail is contained in:

- regulations issued by the Ministry of Agriculture, Fisheries and Food and its sucesssor, the Department for the Environment, Food, and Rural Affairs (DEFRA) and the Department of Health, as advised by the Food Standards Agency and other specialist committees
- European Union legislation.

Enforcement of food legislation is the responsibility of local food authorities, who appoint authorized officers, public analysts and food examiners.

Students should understand that the purpose of food legislation is to protect the health and pocket of the consumer:

- traditionally, in a 'negative' sense, by preventing undesirable practices such as the sale of adulterated, contaminated and low-quality food, the use of additives and the use of misleading labels and advertisements

- more recently, in a 'positive' sense, by encouraging good practices such as beneficial compositional and nutritional standards and informative labelling.

Students should discuss the main elements of the Food Safety Act 1990 including the four principal criminal offences. A brief account of some cases has been included in the *Students' book* to make the discussions more interesting. It may be thought that these cases illustrate that, although the legislative provisions may appear to be unambiguous, the outcome of litigation is not always certain when lawyers and courts become involved. Students are not expected to remember the names and details of cases: they have been included to enable interested students to delve deeper. However, students should be familiar with, and remember, the main provisions of the Food Safety Act 1990.

Students should understand the importance of enforcement procedures to ensure compliance with the substantive provisions of food legislation, particularly the enforcement powers to deal with food safety, which were significantly strengthened by the Food Safety Act 1990.

Students should also understand the role of government regulations, codes of practice and European Union legislation. They should discuss the subject matter of the most recent developments:
- additives
- irradiation
- claims
- labelling (including nutrition labelling)
- contact materials.

Finally, it should be noted that only a few sections of the Food Safety Act 1990 have been considered. It should be pointed out to students that the Act covers many more aspects of food law.

Summary

At the end of this chapter students should:

1 recall the main objectives and provisions of current food legislation

2 understand the information on food labels

3 be able to debate the merits or otherwise of different aspects of food legislation.

CHAPTER 8 THE HUNGRY WORLD

Content

8.1 Population growth
8.2 Producing more food
8.3 Feeding everyone
8.4 Perspectives

Timing

One hour.
After the students have studied the chapter on their own, some time should be allowed for discussion.

Objectives

1 To make students more aware of world food problems.
2 To discuss sustainable methods which could be used to overcome the problems.
3 To suggest that we all have moral responsibility to ensure that the present imbalance in the distribution of the world's resources is not maintained indefinitely.

Commentary

The text in the *Students' book* provides several examples to illustrate aspects of the shortage of food and possible responses.

Students should appreciate that the world presents a contrasting situation in agriculture and food consumption between rich and poor. Agriculture in the rich, developed world is sophisticated and highly technological. In the developing world it is based often on small farms and it is a struggle to provide enough to feed individual families.

Food problems are complex and solutions may be approached in many ways, some ways more realistic than others. It has been attributed to three main factors: growth in the world population, disparity in the distribution of the world's food supplies, and insufficient production of food.

Health care, social development, literacy and economic progress advance independently. These produce a climate of awareness, which is a prerequisite for fighting hunger and disease. Many countries have shown that social development, literacy and economic progress help to limit population growth. Countries where birth rates have declined most rapidly have been those which have spread the benefits of development equally. Giving people hope for a better life by improving their health, raising education standards, and ensuring adequate food supplies for all has reduced the birth rate.

It is important that students should be aware that the problems are not just due to an increase in the world population, but are also the result of poor distribution networks and simple poverty. They should appreciate that there is no such thing as a 'world food problem', but there are instead many individual problems – each country or region having its own local conditions.

Interest and concern are best developed by current examples so students could be encouraged to keep a file of cuttings from newspapers and magazines. These could be added to the 'bulletin board' suggested in Chapter 1. The web links on www.chemistry-react.org may also help.

It is important for students to realize the contribution that can be made by a scientific evaluation of situations. There are many examples of failed initiatives resulting from inadequate analysis and too much weight given to economic and political considerations. We have to learn from our mistakes: the development of integrated pest control is one example of a more balanced approach.

Summary

At the end of this chapter students should:

1 appreciate that the World presents a contrasting situation in agriculture and food consumption between rich and poor

2 discuss the factors involved in food shortages and strategies for providing more food in areas of shortage

3 know about the value of sustainable development.

ANSWERS TO EXAMINATION QUESTIONS

A1 Nutrients needed for:

(i) Proteins (etc.) and example of a food. (2)
(ii) Fats (etc.) and example of a food. (2)
(iii) Vitamins (etc.) and example of a food. (2)
Foods for a basic ration (including vitamins).(2)
Problem of obesity due to quantity and balance of nutrients. (2)

Total 10 marks

A2 (i) Suitable *diagram*. (2)
(ii) Energy reserve; Insulation and protection of organs; Fat soluble vitamins. Any two (2)
(iii) Unsaturated contain double bonds. (1)
Unsaturated are liquids/saturated tend to be solids. (2)
(iv) Hydrogenated at 180 °C using a nickel catalyst. (2)
(v) Certain fats provide essential fatty acids. (1)
Absence of which results in disorders (such as eczema). (1)
(vi) Saturated fats linked with cardiovascular disease, heart attacks and strokes. (1)

Total 12 marks

A3 (i) Correct *displayed formulae* for each amino acid and the peptide link. (3)
(ii) Hydrogen bonding, ionic bonding and description. (4)
(iii) Dipole–dipole attractions, hydrogen bonding, ionic bonding. (2)
(iv) The amino acids the human body cannot synthesize. (1)

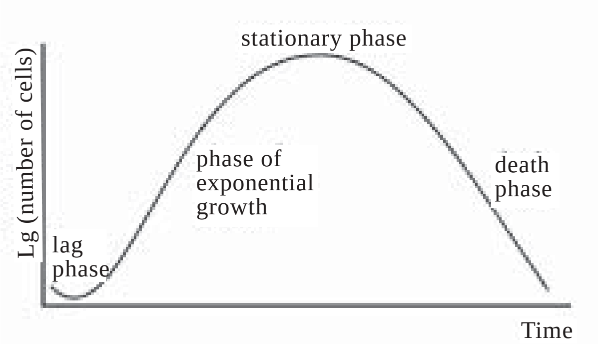
Total 10 marks

A4 (i) Carbohydrate. (1)
Allow cereals, potatoes, bananas, fruit, bread, rice, pasta; flour; cornflour, oatmeal, sugar. (1)
(ii) Relative cost of rearing animals compared with growing plants. (2)

Total 4 marks

A5 (i) Pathogens: food poisoning organisms. (1)
Spoilage organisms: make food unpalatable, not dangerous to health. (1)
(ii) *Staphylococcus*; *Lysteria*; *Clostridium* (botulinum); *Clostridium welchii* (salmonellae). Any two (2)
(iii) Cheese manufacture, yogurt, vinegar etc. Any one (1)
(iv) Shape of curve. (2)
Labelling of section. (2)
(v) Convenient scale for very large population numbers. (1)
(vi) Yeasts and/or moulds and/or enzymes; fungi and enzymes. (2)

Total 12 marks



A6 (i) Unhygienic conditions: contamination by dirt on udder/dairy equipment/hands of milker; growth during storage and transport, temperature control. Any two (2)
(ii) Wash udder (and hands) before milking; wash equipment before and after milking with suitable mild disinfectant; wear protective clothing; store milk under cool conditions; transport milk to factories as soon as possible. Any two (2)
(iii) Pasteurised milk: milk heated rapidly to 72 °C, held for 15 seconds, then cooled rapidly. (2)
Advantages: pathogens are killed, made inactive (many enzymes, e.g. lipases are destroyed); fewer vitamins are destroyed than in sterilization; little effect on taste. Any two (2)
Disadvantages: keeps only slightly longer than fresh milk; sour pasteurized milk has an odour far worse than untreated milk. Any one (1)
milk: milk bottled, sealed and heated to above its boiling point for 20–60 minutes. (2)
Advantages: all micro-organisms destroyed; keeps indefinitely; no need to store in a cool place. Any two (2)
Disadvantages: taste is affected; heat labile vitamins are destroyed. Any one (1)

Total 14 marks

A7 (i) Immersion in boiling water for a short time (1)
Inactivates enzymes present. (1)
(ii) Liquor inhibits growth of bacteria (better preservative). (1)
(iii) Air is replaced by steam (which condenses when sealed and forms a vacuum in the can). (1)
(iv) Fruit more acidic (enzymes more easily denatured at low pH). (1)
Fruit less contaminated than vegetables (which are grown in the soil). (1)

Total 6 marks

A8 (i) Freezing: limits deterioration, lowers rates of reaction. (2)

(ii) Dehydration: limits deterioration, reduces microbial and enzyme activity. (2)

(iii) Canning: distroys micro-organisms and enzymes. (2)

Food legislation is necessary to maintain the quality and purity of food. (2)

Total 8 marks

B1 (i) Provides acid conditions; inactivates the enzyme ascorbic acid oxidase (and thus extracts ascorbic acid from the food). (2)

(ii) Blue in water; colourless when reduced by ascorbic acid; red in acid conditions. (3)

(iii) Uncooked 10/25 x 250 x 0.3 x 2 = 60 mg per 100 g

Cooked 4/25 x 250 x 0.3 x 2 = 24 mg per 100 g (4)

(iv) % less = 36/60 x 100 = 60%. (1)

(v) Oxidation: vitamin C oxidized by oxygen in air and water

Solubility: vitamin C leached out into water (greater effects at higher temperatures). (2)

(vi) Add to boiling water and/or bring to boil quickly to destroy oxidase and reduce oxidation.

Use small quantity of water to reduce amount of vitamin C leached out.

Reduce cooking time by cutting up the cabbage, using a microwave or pressure cooker.

Any two (3)

Total 15 marks

B2 (i) Apple slices placed in air as control. Compare with slices placed in other environments, nitrogen, vacuum, and water. Time to brown is vacuum > nitrogen > water > air. (5)

(ii) Homogenate of apples split into three samples:

A Keep at room temperature

B Immerse in water bath at 40–50 °C

C Boil for one minute and cool tube in cold water.

Rate of browning is **B** > **A** > **C**. (5)

Choice of apple variety; limit oxygen access; inhibit enzyme. Any two (2)

Total 12 marks

B3 (i) Give a more attractive whiter crumb; give enhanced visco-elastic dough properties; (due to oxidation); are added vitamins, increase various mineral/ion contents e.g. calcium.

Any two (2)

(ii) Ascorbic acid. Pour 2% aqueous iodine solution over wet flour, I_2 reduced to $I^-(aq)$, presence of ascorbic acid indicated by white flecks.

Iron. 10% potassium thiocyanate/dilute hydrochloric acid added to dry flour, after 10–20 minutes red spots indicate presence of iron.

Potassium peroxodisulphate. Any two (6)

(iii) The SDS test. (3)

(iv) Mix starch and water (reasonable quantities) in a test tube. Heat suspension in beakers of water at range of temperatures and then cool. Remove a drop of suspension and examine on a slide under a microscope. Look for swelling and bursting of starch granules. (4)

Total 15 marks

C1 *Mark by impression.*

Nutrients required, availability from plants and animals. Knowledge of the components of a balanced diet. (5)

Knowledge of the relative inefficiency of animals as protein sources, importance in world picture.

(2)

Ethical issues. (2)

Total 9 marks

C2 Due to handling of food, or dirty dish with residual spores. Cooling food ideal medium for bacterial growth. Reheating destroys bacteria, not toxins. (4)

Two pathogens: *Salmonellae*; *staphylococcus aureus*; *Clostridium bolulinum*; *Clostridium welchi*. (2)

Total 6 marks

C3 *Mark by impression.*

Types of micro-organism. (2)

Methods of prevention. (5)

Standards of hygiene. (2)

Total 9 marks

C4 (i) Four criminal offences: see *Students'book*, page 37. (4)

(ii) Nutrition label: information about protein, fat and carbohydrate content and energy. (2)

List of ingredients: substances in the product, must be approved additives. (2)

Date-mark: date up to which the food will retain its essential qualities. (2)

Total 10 marks

C5 Factors such as taste, texture, colour, religious and social attitudes. (2)

(i) Irrigation, fertilizers, plant breeding, better farming/fishing techniques, alternative plant protein sources. (5)

(ii) Yeasts, bacteria grown on petroleum, algae etc. (2)

Total 9 marks

C6 *Mark by impression.*

(i) Irrigation, fertilizers, and new varieties (but problems with large-scale development and over-dependence on one variety, pollution). (3)

(ii) New foods from non-traditional sources (but problems of acceptability and high technology in developing countries). (3)

(iii) Better processing, storage and protection from spoilage (but problems with chemical treatments). (3)

Total 9 marks

Experiment 2.7a Investigating the glucose content of drinks

Each group of students will need:

Apparatus for titration, 25 cm^3 pipette and safety filter,
50 cm^3 burette, 250 cm^3 wide-mouth conical flask
Bunsen burner, tripod, gauze and heatproof mat
Quantitative Benedict's solution, 110 cm^3
Sodium carbonate, anhydrous, 40 g IRRITANT
0.50% glucose solution
1% methylene blue indicator (optional)
Drinks containing glucose
Boiling stones

Procedure

The quantities suggested are sufficient for four titrations. This is not an easy titration to perform and the *Students' book* describes the procedure to follow in order to obtain accurate results. Results correct to only $^1/_2$ cm^3 are sufficient to introduce the method.

It is not necessary to dissolve all the sodium carbonate before starting the titration. The methylene blue indicator will reoxidize on the surface of the solution.

Quantitative Benedict's solution can be purchased, or prepared using the following method. Only the copper sulphate need be measured accurately, and potassium salts can be substituted for sodium salts.

Dissolve in about 600 cm^3 of warm water, filtering the solution if necessary:
290 g sodium carbonate 10-water IRRITANT
200 g trisodium citrate 2-water
125 g potassium thiocyanate. HARMFUL

Dissolve in about 100 cm^3 of water
18.0 g copper sulphate 5-water HARMFUL

Mix the two solutions, add 5 cm^3 0.1M potassium hexacyanoferrate(II), and make up to exactly 1.0 dm^3.

National Centre for Biotechnology Education (NCBE) supply a special pack for this Food Science special study.
See 'Enzymes for education' on their website.
NCBE, School of Food Biosciences, University of Reading, Whiteknights, PO Box 226 Reading RG6 6AP
tel 0118 987 37 43
web www.ncbe.reading.ac.uk

Experiment 2.7b Investigating the effect of cooking on the vitamin C content of cabbage

Each group of students will need:

Apparatus for titration, 25 cm^3 pipette, 50 cm^3 burette, 250 cm^3 conical flask
Bunsen burner, tripod, gauze and heatproof mat
Measuring cylinder, 500 cm^3 and 250 cm^3
Beaker, 250 cm^3
Liquidizer (subject to portable electric appliance test) or large pestle and mortar
Filter funnel
Muslin for filtration
Stop clock
Cabbage, 100 g
5% phosphoric(v) acid solution, 600 cm^3
2,6-dichlorophenolindophenol (dcpip) (0.4 g dm^{-3}) in water, 100 cm^3
Ascorbic acid (0.20 g dm^{-3}) in
5% phosphoric(v) acid solution, 75 cm^3
Pure water, which has been boiled to remove dissolved air and then allowed to cool (see Note below)

(Note that distilled water, if not freshly prepared, contains enough dissolved oxygen to interfere with the results of the vitamin C determination. Consequently all purified water should be boiled and cooled just before being used.)

Preparation of 2,6-dichlorophenolindophenol indicator solution

2,6-dichlorophenolindophenol (dcpip) is a dye which is blue when dissolved in water, is red in acid conditions, and is reduced by ascorbic acid to a colourless compound. It is used in a titration for estimating the concentration of vitamin C in food. All dyes, especially the direct dyes, should be treated as HARMFUL.

Dissolve 0.4 g of dcpip in 200 cm^3 of hot distilled water, filter the solution, and make the volume up to 1 dm^3. The dye does not keep well and should be stored in a cool dark place.

Standardization of the indicator solution

It is not possible to make up the indicator solution accurately and it is advisable to standardize it by titrating against a standard solution of ascorbic acid (0.20 g dm^{-3}). The standard solution may be made up by dissolving 0.20 g of ascorbic acid in 1 dm^3 of 5% phosphoric(v) acid solution.

As part of the experiment, the students are expected to standardize the solution by titrating 25.0 cm^3 of the standard ascorbic acid solution with the indicator solution, and to calculate the dye factor (F). The dye factor is the number of mg of ascorbic acid equivalent to 1 cm^3 of the indicator solution.

Procedure

The amount of sample taken will depend on the vegetable under investigation.

Use about 50 g of cabbage. This will give a titration of about 10 cm^3 of dye solution. The amount of vitamin C in a given vegetable or fruit may vary considerably. This is due to natural variations and to losses during the time between harvesting and consumption.

The purpose of the 5% phosphoric(v) acid solution is to provide acid conditions to inactivate the enzyme ascorbic acid oxidase and to extract the ascorbic acid from the food.

For information

Since vitamin C is water-soluble it is readily leached out. Washing and boiling considerably reduce the vitamin C content. Boiling in a large amount of water will increase the loss; steaming, on the other hand, will reduce the loss, unless it is carried out for a long time.

The presence of the enzyme ascorbic acid oxidase will readily destroy the vitamin C. By putting vegetables in small amounts of hot water, the enzyme is destroyed before it can have any effect. On the other hand, if vegetables are put in cold water and brought to the boil slowly, or if the water is cooled by putting a large amount of cold vegetables in the hot water, the enzyme can destroy a large proportion of the vitamin C before it is destroyed. If vegetables are put in briskly boiling water, although a large proportion of the vitamin C will be leached out, very little will be destroyed.

Brussels sprouts	25–50%
Cabbage	40–60%
Cauliflower	25–40%
Potatoes	15–30%
Lettuce	50–70%

Percentage of ascorbic acid lost in cooking

The minimum quantity of water should be used in cooking vegetables so that large amounts of vitamin C are not dissolved. This is very important with vegetables such as cabbage, which have a large surface area from which the vitamin can be lost. With potatoes, which have a smaller surface area, and in which gelatinization of the starch prevents the diffusion and the subsequent loss of vitamin C, cooking has a much smaller effect on the vitamin C lost.

Cooked vegetables should not be kept hot for long periods before being eaten, because this can destroy a large proportion of the vitamin C. It has been found that approximately 25% of the vitamin C of cooked vegetables is lost on keeping hot for 15 minutes, and 75% on keeping hot for 90 minutes.

3.7 Investigating texture and taste

⚠ HAZARD It is contrary to COSHH regulations to eat or drink in any laboratory which could be contaminated with hazardous chemicals. These tasting experiments must therefore be conducted in a domestic science room or another room where eating is permitted.

When food is being used in experiments, the temptation for the students to sample it or to finish off unused portions is very great. The dangers of eating any food in a chemistry laboratory are very obvious. An additional hazard in food experiments is for a treated sample to be mistaken for an unused sample.

It is most important to impose a rule that, except for properly organized tasting experiments, nothing should be eaten during this Special Study, and none of the material should be taken from the laboratory or tasting sessions.

It is also important to ensure that all material which has been used in the experiments be gathered together at the end of the period and, if finished with, taken to a dustbin. This avoids the possibility of it being eaten by students from other classes or by a cleaner.

Experiment 3.7a The effect of calcium ions on the texture and flavour of peas

⚠ HAZARD The peas used in this experiment will be tasted. Glassware should be washed and dried separately from other laboratory apparatus. Chemicals should be taken from fresh bottles or from bottles kept apart specially for this Food science special study.

Each group of students will need:

Bunsen burner, tripod, gauze and heatproof mat
4 beakers, 400 cm^3
4 watch-glasses to cover the beakers
Measuring cylinder, 100 cm^3
Stop clock
Fork or spoon

Separate 30 g samples of dried peas which have been soaked overnight in the following solutions:
1 pure water
2 tap water
3 2% calcium chloride solution
4 4% calcium chloride solution.

Procedure

Solid calcium chloride 6-hydrate is IRRITANT.

Students will need about 30 g of each soaked sample; 15 g of dried peas need about 50 cm^3 of solution and convert to approximately 30 g of soaked peas.

It is important that the samples should be simmered for approximately the same length of time. Students will find that increasing the concentration of calcium chloride solution produces a tougher pea and one which is less likely to break up. However, if the concentration is too high, the flavour may be affected and the colour bleached.

Experiment 3.7b Taste

⚠ HAZARD The solutions used in this experiment will be tasted. Glassware should be washed and dried separately from other laboratory apparatus. Chemicals should be taken from fresh bottles or from bottles kept apart specially for this *Food science* special study..

Each student will need:

4 drinking straws (preferably from a new packet)

Access to:

The following labelled solutions:
A sodium chloride solution, 2% and 4%
B citric acid monohydrate solution, 0.2% and 0.4%
C sucrose solution, 2% and 4%
D caffeine solution, 0.2% and 0.4%

Drinking water and disposable plastic cups

Procedure

Solid caffeine is TOXIC

The four solutions represent the four basic tastes: salt, sour, sweet and bitter respectively. The students should first taste each of the less concentrated solutions and see whether they can detect any taste. If they can detect the taste they should try to identify it as salt, sour, sweet or bitter. Those who cannot detect the flavours should be given the more concentrated solutions to taste.

Experiment 3.7c The tongue and the primary taste sensations

⚠ HAZARD The solutions used in this experiment will be tasted. Glassware should be washed and dried separately from other laboratory apparatus. Chemicals should be taken from fresh bottles or from bottles kept apart specially for this special study.

Each student will need:

4 drinking straws (preferably from a new packet)

Access to:

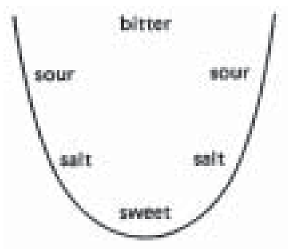
The following solutions:
Sodium chloride solution, 4%
Citric acid solution, 0.4%
Sucrose solution, 4%
Caffeine solution, 0.4%

Drinking water and clean cups

Procedure

Solid caffeine is HARMFUL

The students should work in pairs. The tester should rinse his or her mouth out with water after each sample is put on the tongue, in preparation for the next sample.



Regions of the tongue where primary taste sensations are detected.

4.6 Investigating browning reactions in fruit and vegetables

⚠ HAZARD The benzene derivatives used in solutions A to D are all HARMFUL. Phenol is TOXIC and CORROSIVE and readily absorbed through the skin. Protective gloves should therefore be worn when preparing and using phenol solutions, and particular care taken to wipe up any spillages at once.

Once started, the students can work at their own rate through the experiments. The teacher should ensure that enough correct information is extracted from each experiment.

Experiment 4.6a is carried out first to establish that discolouration is due to substrates such as benzene-1,2-diol and benzene-1,2,3-triol. This is so that benzene-1,2-diol can be added to the samples in the subsequent experiments to intensify the colour and to accelerate the rate of browning.

Experiment 4.6a Which substances are involved in the browning reaction?

Each group of students will need:

Protective gloves
Apple or potato
Tweezers or tongs
Knife
6 watch-glasses or Petri dishes

Access to:

1% aqueous solutions of the following in labelled bottles with droppers:

A benzene-1,2-diol (catechol)
B benzene-1,2,3-triol (pyrogallol)
C benzene-1,3-diol (resorcinol)
D benzene-1,4-diol (hydroquinone)
E phenol HARMFUL
F pure water

Procedure

Remind students about the rules for the safe handling and disposal of food samples.

Benzene-1,2-diol and benzene-1,2,3-triol should cause discolouration very rapidly, but the other compounds react only slowly. For browning to take place a benzene-1,2-diol group is required.

Experiment 4.6b When does the browning reaction take place?

Each group of students will need:

Apple or potato
Tweezers or tongs
Knife
4 watch-glasses or Petri dishes

Access to:

1% aqueous benzene-1,2-diol in a bottle with a dropper
Liquidizer

Procedure

Pulping produces extensive cell damage and allows rapid diffusion of oxygen throughout the tissue. Intact plant cells have a reducing system designed to reduce oxygen, in a controlled way, so as to provide energy for the cell. When the cell is damaged, its reducing properties are lost. Furthermore, pulping destroys the cell and causes the enzymes and substrates, which are normally kept apart, to mix.

Rapid discolouration of a freshly-cut surface suggests that the reaction is an oxidation, and, as it is rapid, possibly enzymic.

When an apple is broken it tends to break between cells rather than through cells. This breaking causes less cell damage and hence less discolouration, than cutting.

Bruising has the same effect as pulping.

Experiment 4.6c Is the reaction due to micro-organisms?

Each group of students will need:

Protective gloves
Half an apple or potato
Knife
Tweezers or tongs
2 watch-glasses or Petri dishes
Beaker, 100 cm^3
Bunsen burner, tripod, gauze and heatproof mat
Thermometer, 0–100 °C
Stop clock
Pure water

Access to:

1% aqueous phenol solution in bottle with dropper HARMFUL
1% aqueous benzene-1,2-diol solution in bottle with dropper

Procedure

The rapidity of the browning reaction suggests that the spoilage is too fast to be microbial. Also, the interior of apples or potatoes is normally free from bacteria.

Washing with 1% aqueous phenol solution should kill off any micro-organisms but will not alter the rate of browning.

Short heat treatment should greatly reduce browning. Sample **A** should brown more slowly than sample **C**. If it were a non-enzymic reaction, the rate should be greater at a higher temperature. The fact that it is slower indicates that the enzyme polyphenol oxidase has been destroyed by heat.

Experiment 4.6d Does the reaction require air or some part of the air?

Each group of students will need:

Quarter of an apple or potato
Knife
3 boiling-tubes equipped with delivery-tubes and clips (see the diagram below)
Tweezers or tongs
Stop clock

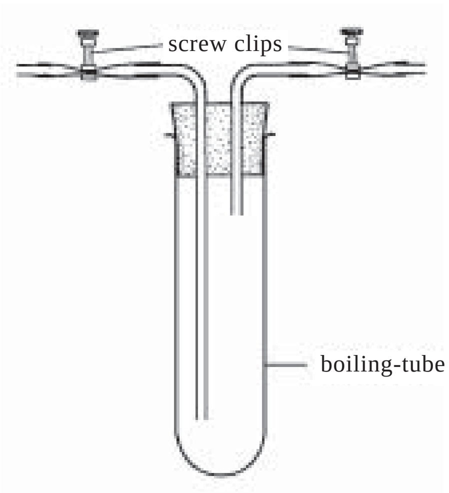
Access to:

1% aqueous benzene-1,2-diol, in a bottle with a dropper
Gas supply, oxygen, nitrogen, carbon dioxide

Procedure

Students will need access to gas cylinders, or generators, supplying oxygen, nitrogen and carbon dioxide.

The students should now be able to summarize the reaction as occurring in damaged tissue and being an enzyme-catalysed oxidation of compounds containing a benzene-1,2-diol group.



Gas apparatus

Experiment 4.6e Can ascorbic acid be used to control the browning reaction?

Each group of students will need:

Apple or potato
Knife
Tweezers or tongs
6 watch-glasses or Petri dishes
Stop clock

Access to:

1% aqueous benzene-1,2-diol solution in bottle with dropper

Labelled beakers containing aqueous solutions of ascorbic acid having the following concentrations:
A 5%, **B** 3.5%, **C** 2.5%, **D** 2%, **E** 1%, and **F** pure water

Procedure

Students should observe a delay period before browning starts. The delay period increases with increasing concentration of ascorbic acid. This is intended to be a qualitative test. The students should place the samples in order of increased delay period.

Ascorbic acid acts by reducing the quinone, as it is formed, back to the hydroquinone. It is itself oxidized in the process. Thus no pigment can be formed until all the ascorbic acid is oxidized, but once this has occurred the browning reaction proceeds at its normal rate. However, the enzyme slowly loses its activity during the reaction and so, if enough ascorbic acid is present, the enzyme loses its activity before all the ascorbic acid is oxidized and no discolouration occurs.

Ascorbic acid (vitamin C) is widely distributed in nature, acting as a control on the redox systems in living cells. It has a great advantage as an antioxidant in the food industry because it is completely harmless when added to food and is a nutrient (vitamin).

Experiment 4.6f Controlling browning by inactivating the enzyme

Each group of students will need:

Protective gloves
Apple or potato
Knife
Tweezers or tongs
Beaker, 100 cm^3
8 watch-glasses or Petri dishes
Stop clock
Bunsen burner, tripod, gauze and heatproof mat

Access to:

1% aqueous benzene-1,2-diol solution in a bottle with a dropper
Labelled beakers containing the following aqueous solutions:
A 2% (0.5M) hydrochloric acid
B 2% citric acid
C 2% sodium hydrogensulphite (gives TOXIC gas with acid)
D 2% sodium chloride
E 2% sucrose
F boilingwater
G pure cold water

Procedure

Enzyme activity is at its greatest between pH 6.0 and 8.0. Outside this range the rate of browning is greatly reduced. Below pH 3.0, the reaction is almost completely inhibited. The natural pH of apples is between 3.0 and 4.0, and that of potatoes is between 5.0 and 6.0, depending on ripeness, variety, and the time of year. Acids may be added to reduce browning. Citric and malic acids occur naturally in fruits and can be added to fruits without significantly affecting their flavour.

Sulphur dioxide is an enzyme inhibitor and is commonly used as a preservative in food. It not act by bleaching the colour but by preventing colour formation: it is a reducing agent. Sulphur dioxide is TOXIC and CORROSIVE.

Soaking in 2% sodium chloride or 2% sugar solution should delay or stop browning, but this will affect the flavour. Sodium chloride inhibits the enzyme mainly by raising the ionic concentration. Sucrose acts mainly by reducing the solubility of oxygen in the surface tissues.

Sodium fluoride, which is TOXIC, will inhibit enzyme activity. The effect may be demonstrated, taking care.

Experiment 4.7a Making curd from milk

Each group of students will need:

4 boiling tubes
Water bath at 37 °C
Whole pasteurized milk, 80 cm^3
Rennet essence, 1 cm^3
Maxiren, 1 cm^3
Rennilase™, 1 cm^3

Optional:

The same materials plus:
1M acids and 1M bases (acids may be IRRITANT or CORROSIVE depending on which is used; bases are CORROSIVE)

Notes

Rennet essence can be bought from delicatessens and health food shops; Maxiren from a genetically modified yeast and Rennilase™, a fungal protease, can be bought from the National Centre for Biotechnology Education (NCBE) – see below.

Procedure

The process depends on a protease enzyme such as chymosin breaking specific bonds in a glycopeptide on the surface of soluble calcium caseinate particles in the milk. The caseinate can then reform into a relatively insoluble form which coagulates in the presence of calcium ions.

The enzymes should be stored in a refrigerator where they will maintain their full activity for at least six months.

National Centre for Biotechnology Education (NCBE) supply a special pack for this Food Science special study. See 'Enzymes for education' on their website.
NCBE, School of Food Biosciences, University of Reading, Whiteknights, PO Box 226 Reading RG6 6AP
tel 0118 987 37 43
web www.ncbe.reading.ac.uk

Experiment 4.7b Making whey syrup using an immobolized enzyme

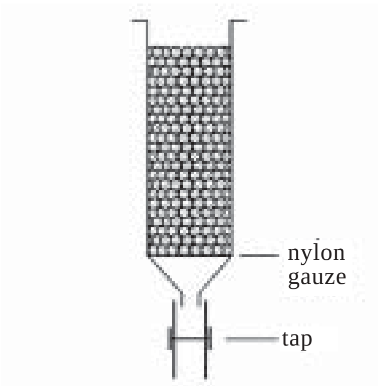
Each group of students will need:

2 plastic syringes, 10 cm^3, one fitted with filter and stop tap (see the diagram below)
Beaker, 250 cm^3
2 beakers, 100 cm^3
Strainer (plastic for tea)
Lactase enzyme, 2 cm^3
2% sodium alginate solution, 8 cm^3
0.1M calcium chloride, 100 cm^3
8% whey solution, 50 cm^3
Glucose test strips, semi-quantitative

Notes

Whey powder and Lactozym™ can be bought from the National Centre for Biotechnology Education (see below) and semi-quantitative diabetic glucose test strips can be bought from pharmacists.

The lactase enzyme should be stored in a refrigerator where it will maintain its full activity for at least six months.



Column for enzyme beads

6.7 Investigating flour

Experiment 6.7a The SDS sedimentation test for gluten

Each group of students will need:

2 measuring cylinders, 50 cm^3
2 stoppered measuring cylinders, 100 cm^3
Stop clock
Bakers' flour (higher gluten content), 6 g
Soft cake or biscuit flour (lower gluten content), 6 g
SDS-lactic acid test solution, 100 cm^3

Procedure

The SDS-lactic acid solution is prepared from

Sodium dodecyl sulphate (SDS), 20 g dm^{-3}
Lactic acid, 1 part 88% aqueous solution CORROSIVE mixed with 8 parts water

The test solution consists of 1 dm^3 of SDS solution mixed with 20 cm^3 diluted lactic acid solution.

The method described in the *Students' book* is based on the standard industrial method. In industry the flour would be produced by a standard grinding procedure, the quantity of flour would be adjusted for moisture content (5.7 g for 10% moisture, 6.1 g for 17%), and the temperature would be controlled to 20±2 °C.

Strong flour and plain flour should give comparable results; 'superfine' flour is likely to give an anomalous result.

Extracting gluten from flour: Alternative to Experiment 6.7a

As an alternative or additional experiment students could use the instructions given on the next page to extract some gluten from flour.

Each group of students will need:

Bunsen burner, tripod, gauze and heatproof mat
2 large evaporating dishes, or bowls
Measuring cylinder, 50 cm^3
2 beakers, 250 cm^3
Glass rod
Grease-proof paper and scissors

Access to:

Bakers' flour (higher gluten content)
Soft cake or biscuit flour (lower gluten content)
Iodine solution (1 g KI plus 0.05 g I_2 in 100 cm^3 of water) HARMFUL

Experiment 6.7b Gelatinization temperature of starch

Each group of students will need:

Measuring cylinder, 10 cm^3
Microscope (with two pieces of Polaroid)
Spatula
Thermometer, 0–100 °C
Test-tubes
Water bath (a large beaker)
Dropping pipette or glass rod
Access to:
Maize starch (cornflour)
Wheat starch
Potato starch

Procedure

Wheat and corn starches gelatinize at a lower temperature than potato starch. Students need not try both methods. If time is a problem then method 2 is quicker.

Two pieces of Polaroid can be used to turn a junior microscope into a polarizing microscope. With crossed Polaroids the 'Maltese Cross' pattern of starch grains shows up in a spectacular way. The pattern disappears as the grains swell and gelatinize.

Experiment 6.7a (alternative) Extracting gluten from flour

Instructions for students

Procedure

a Slowly mix about 30 cm^3 of pure water with 50 g of one of the flour samples in a large evaporating dish or bowl, using a glass rod, to make a dough. The dough should be homogeneous and have the consistency of a very stiff chewing-gum. Allow the dough to stand for about 15 minutes under warm water in a beaker.

b Knead the dough ball under a slow stream of tap water. The starch will be washed away as a milky suspension and the water-insoluble gluten will remain.

c When the water is starch free (how can you test?), squeeze out excess water from the gluten. Mould the gluten in your fingers, drying them occasionally.

d When free water has been reduced the gluten suddenly becomes very sticky. Put it on grease-proof paper and weigh it. Repeat for the other flour.

e Stretch both gluten samples by hand and note the consistency and springiness. Boil the gluten ball for three minutes in water. What has happened to the gluten?

Photocopy these instructions for students

Experiment 6.7c Comparison of flour colour, and qualitative tests for flour improvers

Each group of students will need:

4 Petri dishes with lids
Spatula
Plastic washing-up bowl, or sink with plug
Standard bakers' flour, see note
Biscuit flour, see note
10% aqueous potassium thiocyanate solution, 1 cm^3
2M hydrochloric acid, 1 cm^3 IRRITANT
2% aqueous iodine solution (in KI), 1 cm^3
Test-tubes

The teacher may need:

0.2% solution of benzene-1,2-diol in ethanol, 1 cm^3 HIGHLY FLAMMABLE

Note

Biscuit flours are generally untreated and give no reaction for added vitamin mix or improvers. Standard bakers' flour, however, usually contains a vitamin mix containing iron (in the form of very fine iron filings) and ascorbic acid.

It can be helpful to provide flour samples for these experiments to which ascorbic acid has been added, to give a concentrations of 200 p.p.m. (0.2 g to 1 kg)

Question 1

The darkening is due to the enzyme phenol oxidase, which is mainly in the bran. This reaction can be highlighted as a demonstration by pouring enough 0.2% ethanolic solution of benzene-1,2-diol (TAKE CARE) to just cover the wet flour (on which the enzyme then reacts).

Question 2

The enzyme-catalysed reaction is speeded up by warming.

Question 3

Ascorbic acid is a reducing agent and will reduce the iodine to an iodide. The presence of ascorbic acid will produce white flecks on the surface of the flour which will otherwise be coloured a uniform blue by the starch–iodide reaction.

Question 4

The treated flour will develop a deeper red colour than the control. After 20 minutes the flour containing the iron will show deep red spots, indicating the location of iron particles.