FOOD SPOILAGE

A.4.1 food spoilage Food becoming unfit for consumption, for example, due to chemical or biological contamination.

Most natural foods have a limited life. Perishable food such as: fish, meat, milk and bread have a short lifespan. Other foods keep a considerably longer time but decompose eventually. There are many causes of food spoilage. Enzymes within some foods bring about their destruction, while chemical reactions such as oxidation and rancidity decompose others – but the main single cause of food spoilage is invasion by microorganisms such as moulds, yeasts and bacteria.

Micro-organisms are found everywhere, since the conditions which bring about their growth are readily available. Like humans, they prefer a warm, moist environment, a supply of oxygen and food – and because their nutritional requirements are similar to ours, they readily contaminate our food supplies. When food spoilage is caused by the growth of yeasts and moulds it is self-evident: a furry growth covers the food and it becomes soft and often smells bad. Bacterial contamination is more dangerous because very often the food does not look bad: even though severely infected, it may appear quite normal. The presence of highly dangerous toxins and bacterial spores is often not detected until after an outbreak of food poisoning, when laboratory examination and experiments uncover the infecting agent.

A.4.2 TYPES OF FOOD SPOILAGE

PHYSICAL SPOILAGE: Physical damage to the protective outer layer of food during harvesting, processing or distribution increases the chance of chemical or microbial spoilage. Examples of physical spoilage include:

- Staling of bakery products and components
- Moisture migration between different components
- Physical separation of components or ingredients
- Moisture loss or gain

CHEMICAL SPOILAGE: When animal or vegetable material is removed from its natural source of energy and nutrient supply, chemical changes begin to occur which lead to deterioration in its structure. The two major chemical changes which occur during the processing and storage of foods and lead to a deterioration in sensory quality are lipid oxidation (rancidity) and enzymic browning. Chemical reactions are also responsible for changes in the colour and flavour of foods during processing and storage.
MICROBIAL SPOILAGE: These microorganisms (moulds, yeasts and bacteria) do not cause disease but they spoil food by growing in the food and producing substances which alter colour, texture and odour of the food, making it unfit for human consumption. For example, souring of milk, growth of mould on bread and rotting of fruit and vegetables.

A.4.4 ENZYMIC SPOILAGE

Every living organism uses enzymes of many sorts in its bodily functions as part of its normal life cycle. Enzymes are used in creating life. After death, enzymes play a role in the decomposition of once living tissue. For example, the enzymes in a tomato help it to ripen and enzymes produced by the tomato and whatever fungal and bacterial spoilers are on it cause it to decay. This action is illustrated in the following video clip: www.youtube.com/watch?v=F_8VDUhel2o&feature=related

Watch the following video clips to see what happens to fruit when it rots.
www.youtube.com/watch?v=FgKZp18jJnA&feature=related
www.youtube.com/watch?v=IRiwXMeKoGk&NR=1

A.4.5

MAILLARD BROWNING (NON ENZYMIC BROWNING)

This is a browning reaction which occurs during the roasting, baking, grilling and frying of many foods. A chemical reaction takes place between the amino group of a free amino acid or a free amino group on a protein chain and the carbonyl group of a reducing sugar e.g. glucose. Brown coloured compounds are formed which are responsible for the attractive colour of products such as bread crust, roasted meat, fried potatoes and baked cakes and biscuits. The compounds also give an appetising flavour to the food.

ENZYMIC BROWNING

When the cells of apples, potatoes and some other fruits and vegetables are cut and exposed too the air, enzymes present in the cells bring about an oxidation reaction; colourless compounds are converted into brown-coloured compounds. Browning does not occur in cooked fruits and vegetables since the enzymes are destroyed by heat. Fruits such as apples, pears, bananas, peaches and avocado are prone to discolouration. Watch the following video which illustrates enzymic browning in avocados and potatoes: www.youtube.com/watch?v=XgrhsiY5SGM&feature=related
A.4.6.- A.4.7 RANCIDITY

Most fats and oils do not store very well, they develop off flavours and odours known as rancidity. Rancidity is important when considering the shelf life of a food product. Rancidity is caused by several factors:

- Absorption rancidity
- Oxidative rancidity
- Hydrolytic rancidity

ABSORPTION RANCIDITY: When oils and fats are stored next to strong smelling foods e.g. onions or garlic or products e.g. paints, detergents, disinfectants. The smell is absorbed by the fat or oil making it unpleasant to eat.

OXIDATIVE RANCIDITY: Oxygen from the air can oxidize unsaturated fats producing objectionable flavours. This is the most important and common type of rancidity. It involves a 3 phase process.

1. INITIATION PHASE: In the presence of oxidisers or enzymes an unsaturated hydrocarbon loses a hydrogen to form a free radical (which is very reactive) and oxygen adds at the double bond to form a diradical. Hydroperoxides are produced. Each initiation process produces two free radicals, each of which participate in the chain reaction mechanism.

\[
\text{H} \quad \text{H} \\
\begin{array}{c}
\text{C == C}
\end{array} + \text{O}_2 \rightarrow \text{H} \quad \text{H} \\
\begin{array}{c}
\text{C} \quad \text{C}
\end{array} \\
\text{O} \quad \text{O}
\]

2. PROPOGATION PHASE: The chain reaction is continued. Further oxidation by lipid oxidation products gives rise to the term AUTO-OXIDATION that is often used to refer to this process. Autooxidation - refers to the rate of oxidation which increases as the reaction proceeds. Peroxy radicals, hydroperoxides and new hydrocarbon radicals are formed. The new radical formed then contributes to the chain by reacting with another oxygen molecule.

3. TERMINATION PHASE: Occurs when two radicals interact. This results in relatively unreactive compounds e.g. hydrocarbons, aldehydes and ketones.

Sunlight hastens the process, while traces of metals e.g. copper and iron act as catalysts. Oxidative rancidity does not depend on the presence of impurities or moisture in the oil and can therefore affect pure and refined oils. ANTI-OXIDANTS used to prevent the development of rancidity are reducing agents used to remove the oxygen e.g. butylated hydroxyanisole (BHA) is one of the permitted anti-oxidants added to fats. Vitamin E is an anti-oxidant present naturally in many fats and oils. Anti-oxidants prolong the shelf life of a product.
HYDROLYTIC RANCIDITY: this is caused by the presence of water, which causes triglycerides to split into glycerol and fatty acids. The rate of hydrolysis in the presence of water alone is negligible but hastens if enzymes (lipases) and microorganisms (bacteria, moulds and yeasts) are present. It results in the formation of free fatty acids and soaps (salts of free fatty acids). The oil/fat develops a soapy taste/texture. This is a less common type of rancidity but is quite common in emulsion systems such as butter, margarine and cream.

High temperatures, the presence of moisture, oxygen and light are among the factors that speed up rancidity. Different types of fat and oil show varying degrees of resistance to spoilage. Most vegetable oils deteriorate slowly, animal fats deteriorate quicker and marine (fish) oils, which contain a very high proportion of highly unsaturated fatty acids, deteriorate so rapidly that they are useless for edible purposes unless they are refined and hydrogenated.

A.4.8 water activity (aw) The water in food that is not bound to food molecules, which can support the growth of bacteria, yeasts and fungi, and is measured on a scale of 0 (bone dry) to 1.0 (pure water).

A.4.9.
THE IMPORTANCE OF WATER ACTIVITY (A_w) IN MICROBIAL SPOILAGE
Micro-organisms require water to maintain life. The amount of water available in a food can be described in terms of the WATER ACTIVITY (A_w). Pure water has an A_w = 1.0. The water activity of most fresh foods is 0.99.

Water is required by micro-organisms to maintain normal population growth. Removal of water does not kill the microbes but just stops their growth. In order to prevent the growth of micro-organisms in a food the WATER ACTIVITY (A_w) of the food must be reduced to 0.6 or below.
A.4.10 REASONS FOR PRESERVING FOOD
Foods are preserved to prolong their shelf life. As soon as animals have been slaughtered and plant foods have been harvested deterioration begins. This involves 2 main processes:

1). Cells break down due to enzymes present in the food: this process is known as **AUTOLYSIS**, meaning ‘self destruct’.

2). The disrupted cell structures are vulnerable to the activities of micro-organisms. Micro-organisms cause changes in odour, flavour, colour and texture of food.

For effective food preservation it is necessary to prevent both autolysis and microbial growth.

Reasons for preserving food:
- Extension of the safe storage life of food.
- Safety.
- Acceptability.
- Nutritive value.
- Availability.
- Economic viability.

As an introduction to this section watch the Food Preservation video and answer the questions on the sheet provided.

A.4.11 METHODS OF FOOD PRESERVATION

FREEZING AND CHILLING

Freezing controls the growth of micro-organisms in 2 ways. The growth rate is reduced due to the low temperatures and water is unavailable because it has been converted to ice. Also, the chemical changes in food are slowed down because of the low temperature. Before freezing foods, inedible parts are removed and it is usual to **blanch** fruit and vegetables to **inactivate enzymes**. The number of bacteria is also reduced by blanching.

Commercially, foods are frozen by the quick-freezing process. This method is desirable because ice crystals that form in the food are small; large ice crystals rupture the cell wall and thus change the texture and appearance of food.
METHODS OF FREEZING:

1. **PLATE-FREEZING**: This is the oldest method of the large-scale freezing methods. The food is packed between hollow metal plates and refrigerant is passed through the plates. Suitable foods include fish fillets (frozen into blocks → fish fingers).

2. **BLAST-FREEZING**: This involves exposure of the food to a blast of pre-cooled air (-40°C) in a specially designed tunnel.

3. **FLUIDISED BED-FREEZING**: This is a development of blast-freezing, is suitable for food of small particle size. Suitable foods include: peas, beans, chipped potatoes and soft fruits.

4. **IMMERSION-FREEZING**: This involves placing the food in the refrigerant. Brine (salt water) may be used for fish. This method is not often used.

5. **CRYOGENIC FREEZING**: This method uses liquid nitrogen (-196°C) or carbon dioxide (-78°C). It allows a faster rate of temperature loss, and the frozen food has tiny ice crystals. It is more costly than other methods but it is recommended for foods such as strawberries and prawns.

QUALITY OF FROZEN FOODS

During blanching of fruit and vegetables ascorbic acid (vitamin C) and thiamin (B1) are vulnerable. Nutrients in the form of thaw drip may be lost when foods are thawed – for example, thiamine from meat. Textural changes may occur; soft fruits can become mushy because the cell structure of the fruit collapses.

CHILLING

Chilling is a short term process of preservation. Chilling is based on the principle that microbial activity is reduced in cold storage conditions. At temperatures in the range 0-5°C the growth of most species of micro-organisms is retarded. Chilled foods are prepared foods which, for reasons of safety or quality, are designed to be stored at or below 8 °C for their entire life e.g. salads. The optimum temperature for storage is 5 °C.

Cook chill products are dishes which are cooked and then rapidly chilled between 0 °C-3 °C within 90 minutes. The food is then stored in controlled low temperatures, below 3 °C. The product should be reheated thoroughly (to above 72 °C for 2 minutes) prior to consumption.
IRRADIATION

Although irradiation destroys micro-organisms it has no effect on the enzymes in food, so degradation is not prevented. Food irradiation is permitted in some countries. The commercial development of irradiation is limited due to a number of factors such as the cost of equipment, stringent tests needed for safety and the development of undesirable flavours in certain foods.

IRRADIATED FOOD SYMBOL

POTATOES PRESERVED BY IRRADIATION AFTER 6 MONTHS

QUALITY OF IRRADIATED FOODS

Some small nutritional loss will occur in the food as in all processing techniques.

HEAT TREATMENT

Foods can be preserved by the application of heat in sufficient quantity to kill all micro-organisms and to inactivate enzymes. There are 2 levels of heat processing:

1. PASTEURISATION

This is heat processing designed to kill all pathogenic organisms, and in so doing to kill most spoilage organisms. It is a short term method of preservation and it extends the storage life of the product a little but makes it bacteriologically safe. This process is used in the pasteurisation of milk for example. Raw milk is heated to 72°C for 15 seconds.

QUALITY OF PASTEURISED FOODS: As with all forms of heat treatment of food, there is some nutritional loss. In the case of milk or fruit juice, the vitamin C is affected. There is no significant effect on the organoleptic qualities of the food product.

2. STERILISATION

This is a much more severe heat process aimed to destroy all micro-organisms. Absolute sterility is difficult to obtain as some bacterial spores may survive the process. Commercial sterility is the state achieved in most canning processes, and is heat processing designed to kill virtually all micro-organisms, and most spores, which would be capable of growing during storage. Some organisms can survive the sterilisation process if not processed for enough time or at a high enough temperature, e.g. clostridium botulinum.

QUALITY OF STERILISED FOODS: The sterilisation process is more severe than pasteurisation, and can sometimes affect the appearance and taste of food. In milk, for example, sterilised milk develops a sweeter flavour as the natural sugars in the milk are caramelised at high temperatures. Some people find this flavour unpleasant. As with all forms of heat treatment of food, there is some nutritional loss, especially of vitamin C and B group vitamins.
CANNING
Canning involves the application of heat and aims at destroying micro-organisms and their spores. The heat-treated or sterilised food must be kept in an airtight container to prevent contamination.
Canning is carried out in 6 main stages:
1. The food is cleaned, and inedible parts such as bones in meat and stones in fruit are removed.
2. Vegetables are usually blanched either by immersing them in boiling water or exposing them to steam. Blanching inactivates enzymes in the food, and bubbles of air are driven out of the food, reducing its bulk. (REF. PROUDLOVE: page 187-188).
3. The cans are automatically filled. Fruits and vegetables and certain other foods are topped up with liquid such as brine (salt water) or syrup. The filled cans are usually exposed to steam or hot water. This causes air to be driven out.
4. The cans are sealed with a lid in an automatic machine so that they are airtight or hermetic.
5. The cans are sterilised (121°C).
6. The cans are then cooled gradually.

Suitable foods:

ASEPTIC CANNING: This process involves the separate sterilisation of the food and can. The cans are filled in such a way that micro-organisms cannot enter.
QUALITY OF CANNED FOOD:
The sterilisation process causes the loss of heat-sensitive nutrients such as ascorbic acid (vitamin C) and thiamin (vitamin B1). There are also changes in colour, flavour and texture.
ADDITION OF CHEMICALS

§ ACIDS: such as vinegar are used in pickling. The vinegar prevents the growth of micro-organisms. This is because the food is placed in a low pH solution in which micro-organisms cannot grow.

§ PERMITTED CHEMICAL PRESERVATIVES: Preservatives help to reduce or prevent wastage of food through spoilage caused by micro-organisms. Longer shelf life enables a greater variety of products to be kept in store and in the home. Common examples of preservatives include:
- Sorbic acid (E200) used in soft drinks and processed cheese.
- Benzoic acid (E210) used in soft drinks
- Sulphur dioxide (E220) used in dried fruit, dehydrated vegetables, fruit juice, fruit syrup, pickles.
- Potassium nitrate (E252) used in curing bacon, ham and other cured meats.

Fats, oils and foods containing them are subject, over a period of time, to the effects of oxygen in turning the product rancid. Antioxidants are added to such foods to slow down or prevent the process of rancidity (oxidative) and thus extend the shelf life of a product. Common antioxidants include:
- Ascorbic acid (E300) used in fruit drinks
- Propyl gallate (E310) used in vegetable oils and chewing gum
- Butylated hydroxyanisole (E320) used in cheese spread, stock cubes.

REMOVAL OF WATER

Foods may be preserved by the addition of anti-microbial substances such as:

§ SALT: used in the curing of meat such as bacon. The salt or brine (salt solution) reduces the moisture content of the food i.e. it reduces the availability of water (Aw) to micro-organisms. The moisture available to the micro-organism is reduced by OSMOSIS. The salt solution is more concentrated than the cytoplasm inside the cells of the micro-organism. Therefore, water passes out of the cell and the cell becomes dehydrated. With little moisture, micro-organism growth is retarded.

Diagram illustrating the osmotic effect of a salt solution on a bacterial cell.

§ SUGAR: used in the manufacture of jam and crystallised fruit. The addition of a large quantity of sugar inhibits the growth of micro-organisms by making the water in the fruit cells unavailable. Again, the moisture available to the micro-organism is reduced by osmosis. The high temperature used in jamming also destroys any micro-organism.
DEHYDRATION

Traditionally, foods were dried in the sun. The original processes have advanced considerably, and moisture is now removed by the application of heat in a controlled flow of air.

METHODS OF DRYING:

a. SUN DRYING: This method is practical in hot dry climates, but the process is slow and the foods being dried are vulnerable to contamination.
   Suitable foods:
   ___________________________________________________________________

b. FLUIDISED BED-DRYING: Warmed air is circulated around the food while it is agitated to stop it from sticking.
   Suitable foods:
   ___________________________________________________________________

c. SPRAY DRYING: Spray drying is used for liquids. The liquid is sprayed through fine nozzles into a current of hot air. The water evaporates and leaves behind a fine powder.
   Suitable foods:
   ___________________________________________________________________

d. ROLLER DRYING: This is used for pasted foods such as instant breakfast cereals. The paste forms a film on the surface of a heated roller or drum. During the rotation of the roller or drum, the food dries and is finally removed by scrapers.
   Suitable foods:
   ___________________________________________________________________

e. ACCELERATED FREEZE-DRYING (AFD): This involves an initial freezing process which is followed by gradual heating in a vacuum cabinet. During this process ice crystals form and change to vapour without going through the liquid stage (sublimation). The product is porous but differs from its original form. The porous nature of the food makes it suitable for instant re-hydration.
   Suitable foods:
   ___________________________________________________________________

QUALITY OF DRIED FOODS

Drying alters the cellular structure of food. Retinol (vitamin A), thiamin (B1), ascorbic acid (C), and vitamin E are lost in the drying process. Foods with a high fat content are vulnerable to rancidity and discolouration.
MODIFIED ATMOSPHERE PACKAGING (MAP)
MAP is the enclosure of food in a package in which the atmosphere has been changed by altering the proportions of carbon dioxide, oxygen, nitrogen, water vapour and trace gases. The process retards microbial and biochemical activity. Products such as bacon, red meat, poultry and vegetables use this method to increase the shelf life of the product.

VACUUM PACKING
Foods such as meat or cheese are packed in impermeable plastic material, and the air is sucked out under vacuum. This method prevents the growth of aerobic micro-organisms because of the absence of oxygen.

PERMEABLE PACKAGING
Some types of plastic are semi-permeable and allow the transfer of gases such as oxygen and carbon dioxide and water vapour. This type of material is used for foods such as tomatoes, and is useful because it delays ripening and extends the shelf life by more than a week. Other packaging materials are completely permeable. Sometimes crusty bread is packed in a plastic covering dotted with tiny holes. This type of packaging is advantageous because otherwise trapped moisture would condense and the crust would lose its characteristic crispness.
2006

D2. Describe how the pasteurisation of milk increases its shelf life. (2 marks)

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2004

D2. Outline how freezing extends the storage life of ice cream. (2 marks)

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2003

D3. Outline one way in which the safe storage life of bread can be extended. (2 marks)

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SPECIMEN PAPER

1. (b) Explain 2 preservation methods that use raised temperatures to extend the shelf life of foods. Give examples of foods suitable for each technique. (12 marks)

Use file paper to answer this question.
GLOSSARY

**food spoilage** Food becoming unfit for consumption, for example, due to chemical or biological contamination.

**water activity (aw)** The water in food that is not bound to food molecules, which can support the growth of bacteria, yeasts and fungi, and is measured on a scale of 0 (bone dry) to 1.0 (pure water).
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<td>A.4.2 Explain that food spoilage can be caused by physical spoilage, chemical spoilage or microbiological spoilage.</td>
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<td>A.4.3 Explain that the two principal causes of chemical spoilage of food are enzymic spoilage and rancidity.</td>
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<td>A.4.4 Outline the changes that take place in enzymic spoilage.</td>
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<td>A.4.6 Describe three types of rancidity, and outline how rancidity can be prevented.</td>
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<td>A.4.8 Define water activity ($a_w$).</td>
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<td>A.4.9 Describe the importance of water activity in microbial spoilage.</td>
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<td>A.4.10 List the major reasons for preserving foods.</td>
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<td>A.4.11 Describe five methods of preserving food, including chilling, irradiation (pasteurization, sterilization, canning), vacuum packing, use of acids and preservatives, and removal of water (dehydration, use of sugar and/or salt).</td>
<td>Classroom video: FOOD PRESERVATION (25 mins)</td>
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<td>A.4.12</td>
<td>Explain how food preservation methods affect the organoleptic properties of foods.</td>
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<td>A.4.13</td>
<td>Explain how food preservation methods affect the nutritional properties of foods.</td>
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