UNIT 13 DETERIORATIVE FACTORS AND THEIR CONTROL

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13.0 OBJECTIVES

After reading this unit, you should be able to:

- know shelf life and dating of food;
- explain causes of food deterioration;
- know nutritional changes in food;
- describe food borne diseases;
- know food allergies and anti-microbial agents used in food;
- explain enzyme inactivation;
- describe different treatments to keep the food safe; and
- know hygiene and sanitation.

13.1 INTRODUCTION

Deterioration of food can be defined as any decay due to physical or chemical means or undesirable decomposition of constituents by excessive growth of microorganism. Food deterioration is manifested by the reduction in aroma, flavour, textural and nutritional values of foods. In extreme cases, the foods become totally unpalatable and is unfit for human consumption. Some microorganisms are also known to release toxins that may cause damage to health.

13.2 SHELF LIFE AND DATING OF FOODS

All foods have a time of the usefulness i.e. a time limit during which they can be consumed. Shelf life is the time required for a food product to reach to an unacceptable quality. The length of the shelf life of foods will depend on the type of food, processing method, packaging, and storage conditions. It is a practice to add some form of dating system to retail packages of foods so that consumers may have some indication of the shelf life or freshness of the products they buy. Food manufacturers put code dated on their products. The dates of manufacture ("pack date"). The date the product was displayed ("display date"), the date by which the product should be sold ("sell by date"), the last date of maximal quality ("best used by date"), and the date beyond which the product is no longer acceptable ("use by date" or expiry date").

One recent system for monitoring shelf life uses labels or tags on foods that respond to a combination of time and temperature to which the product has been exposed. These are called "time-temperature" indicators and are based on the principle that both time and temperature are important in the spoilage of foods.

13.3 CAUSES OF FOOD DETERIORATION

The major factors affecting food deterioration are: (1) growth and activities of microorganisms, principally bacteria, yeast, and moulds; (2) activities of food enzymes and other chemical reactions within food itself; (3) infestation by insects, parasites, and rodents; (4) inappropriate temperatures; (5) gain or loss of moisture; (6) oxygen (7) light (8) physical stress and (9) time.

These factors can be divided into biological, chemical and physical factors and often they do not operate in isolation. Bacteria, insects, and light, for example, can all be operating simultaneously to spoil food in the field or in a warehouse. Similarly, heat, moisture, and air simultaneously affect the multiplication and activities of bacteria and chemical activities of food enzymes. At any time, many forms of deterioration may take place, depending on the food and environmental conditions. The major types of spoilage of foods are microbiological, biochemical, physical and chemical.

13.3.1 Chemical Reactions

Chemical reactions take place in the presence of atmospheric oxygen and sunlight. Two major chemical changes, which occur during the processing, and storage of fruits and vegetables are lipid oxidation and non-enzymatic browning which deteriorate sensory quality, colour and flavour.

Lipid oxidation is influenced by light, local oxygen concentration, high temperature and the presence of iron and copper, and water activity. Control of these factors can significantly reduce the extent of lipid oxidation or rancidity in foods.

Non-enzymatic browning is one of the major causes of deterioration which takes place during frying, cooking, storage of dried and concentrated foods through Maillard reaction between reducing sugars and amino acids present in the foods and formed black brown insoluble pigments.

13.3.2 Biochemical Reactions

Different biochemical reactions in foods and plants tissues are catalysed by enzymes. They are responsible for certain undesirable or desirable changes in fruits, vegetables and other foods. Examples involving endogenous enzymes include: (a) the post-harvest senescence and spoilage of fruit and vegetables; (b) oxidation of phenols in plant tissues by phenolases leading to enzymic browning; (c) sugar – starch conversion in plant tissues by amylases; (d) post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

Factors responsible for controlling enzymatic activities are: temperature, water activity, pH, chemicals which can inhibit or enhance enzyme activity.

Enzymatic spoilage is the greatest cause of food deterioration. If enzymatic reactions are uncontrolled, the off-odours, and off-colours may develop in foods. In fruit and vegetables, enzyme-induced oxidative breakdown of unsaturated fatty acids occurs extensively which, give characteristic aromas during ripening of fruits. Enzymatic browning take place in apples and potatoes during cutting and peeling and exposed to air, due to the oxidation of phenols by peroxidase and polyphenoloxidase.

Certain changes are produced by enzymes of foods and micro-organisms that contaminate the food. Ripening of banana is due to the enzymes present but after some time the fruit becomes too soft by microorganism enzymes and become unfit to eat. Enzymes convert starch into sugars, proteins into amino acids, and pectin into pectic acids and this change the constituents of food. Enzymes can act between 0^0 and 60^0C but 37^0C is optimum temperature. All enzymes are inactivated at 80^0C.

13.3.3 Physico – Chemical Reaction

Physico-chemical reactions are caused by freezing, burning, drying and bruising of fruits and vegetables during storage, handling and transportation, which result in food deteriorations.

Food processing or storage causes some deterioration in colour of fruits and vegetables due to the degradation of the chlorophyll resulting dull olive-brown colour. Dehydrated green peas and beans packed in glass containers undergo photo-oxidation and loss of desirable colour.

In addition to chlorophyll, anthocyanins and carotenoids also give colour to fresh and processed foods. Anthocyanins form complexes with metals which results in change in the colour of the pigment. Red sour cherries react with tin

and form undesirable purple complex. Carotenoid degradation occurs in foods by oxidation in the presence oxygen, light and heat.

One major undesirable physical change in dried food powders is the absorption of moisture, which results in caking. In general, moisture absorption is associated with increased cohesiveness. Caking does not occur at water activities of less than about 0.4 at ambient temperature.

13.3.4 Microorganism: General Principles, Causes and Growth

Most significant deteriorative changes occur in foods due to microorganisms present in air, soil, water, on fruits, vegetables and foods. They are so small that they can only be seen through microscope. There are three types of microorganisms which cause spoilage: (1) Bacteria, (2) Yeasts (3) Moulds.

Bacteria

Bacteria are minute unicellular microorganisms. The growth of bacteria depends upon food , temperature, pH, moisture and oxygen. Bacteria are much more difficult to kill and are the most common causes of food spoilage. They are present in active form (vegetative stage) or resting form (spore stage). In vegetative stage, bacteria are destroyed at boiling temperature but spores require application of heat (100^0C) for a long time (six hours) or 30 min at 121^0C under 10 lbs pressure.

All forms of bacteria are sensitive to acids and can be killed easily in acidic pH at a temperature of boiling water. So foods with high acid content (all fruits, tomatoes, pickles etc.) are processed at $l00^0$C whereas low acid foods such as corn, peas, beans and all vegetables except tomatoes have to be processed at higher temperature (116^0C) in a steam pressure to kill bacteria. The temperature maintained and the length of time, the food is held vary with kind of foods. Moist heat resistant bacteria are present in the soil, hence, preparation and processing of root vegetables require special care. *Clostridium botulinum* causes spoilage in canned foods.

Bacteria enter through stomata and lenticels. The most common bacteria causing significant reductions in shelf life of fruits and vegetables is the soft rotting species of the genus *Erwinia*. Under suitable conditions they produce large quantities of extracellular enzymes which rapidly macerate the tissue which gives unpleasant off-odours

Most of the pathogens of fruits and vegetables will grow between 6 and 35^0C. Some (*B. cinerea)* will survive and even grow at low temperatures, 1^0C, on agricultural produce, whereas *Botryodiplodia theobromae* or *Aspergillus niger* cause losses in warm regions.

Each kind of bacteria has a definite range of food requirements. Level of moisture in food is important in preventing or allowing the bacterial growth in the food. Bacteria require more moisture than yeasts or moulds. Each bacteria has an optimal temperature at which it grows best. Temperature below and above the optimum adversely affects the growth of bacteria. pH determines the kind of bacteria that well grow on the food. Most bacteria grow best at neutral, pH, however, some bacteria also grow in acid or alkaline media.

On the basis of respiration bacteria are classified as:

- **Aerobic** : They require free oxygen for growth.
- **Anaerobic** : Do not require free oxygen for growth.
- **Facultative** : Grow either with or without free oxygen.

Yeasts

Fungi usually known as yeast are microscopic unicellular organisms, which are non-motile round or oval. Yeasts reproduce or multiply by a process of "budding". The bud when fully mature, breaks away from the mother cell and becomes independent and repeats the process of multiplication. Yeasts require less moisture and acidic pH to grow and do not grow in alkaline medium. Yeasts grow under moderate temperature (25-30 C) in solution containing sugar. Most of the yeasts usually do not grow in media containing more than 65% of sugar or 0.5% acetic acid. Heating at 60 ^{0}C for a few minutes is sufficient to destroy most species of yeasts. Boiling destroys yeast cells and spores effectively. Some yeast grow well in light sugar solution and acidic medium. Some yeasts are very useful in making bread, beer, wine, vinegar and many other fermented products. Yeasts are responsible for fermentation of fruits and fruit products. Yeasts are undesirable when they grow on fruits, juices, squashes, *sharbat*, honey etc. They spoil the appearance, taste, texture and wholesomeness of fruits and fruit products. During active fermentation, yeast can be recognized by formation of bubbles or foam on the surface of the product. Some of yeasts which grow on fruits are *Saccharomyces, Candida,* etc.

Moulds

Moulds are larger and more complex in structure than bacteria or yeast. Moulds are made up of mycelium and spores. They grow in a network of hair like fibres called mycelia and send up fruiting bodies that yield spores. A piece of orange left for a time becomes covered with a whitish or grayish cottony matter

They thrive best in closed, damp and dark situation and require adequate supply of warmth, moisture and air for growth. They are aerobic in nature and require less available moisture and can grow well at 25-30 C. Moulds prefer sugar containing substances like jam, jelly, preserves and other sweet based products. They can grow at wide range of pH (2 to 8.5) but majority grow well at acidic pH. Therefore, they grow nicely on pickles, juices etc. They can grow on many kind of foods especially when temperature, air and humidity are favourable. Their growth can be seen only on the surface of food. They not only consume nutrients present in food thereby lowering the food value but also produce odd by-products, which spoil the flavour, taste and texture of food hence change the quality contents of the entire products.

Majority of moulds are sensitive to heat and are destroyed at 60 C when heated for 30 minutes. Boiling quickly destroys both moulds and their spores. Some of common moulds are *Aspergillus Penicillium*, *Rhizopus* and *Heliminthosporium*.

Insect and Pests, Rodents

The main categories of foods subjects to insects and pest attack are fruits, vegetables, grains and their processed products, and dried fruits. The presence

of insects and pests and their excreta in foods may render products consumable loss, in nutritional quality, production of off-flavours and acceleration of decay processes due to creation of higher temperatures and moisture levels and release of enzymes. The products of insect and pests activities such as webbing, clumped-together food particles and holes can also reduce the food values.

Warm humid environment promote insect growth, although most insects will not breed if the temperature exceeds about 35 C^0 or falls below 10 C^0. Many insects cannot reproduce satisfactorily unless the moisture content of their food is greater than 11%.

Rats and mice carry disease-producing organisms on their feet and/or in their feces and are known to harbour *Salmonella* associated with food-borne disease in humans. Rodents contaminate the food through defecation, urination or when walk over food or food contact surfaces. These animals also destroy intensively human's foods. Rats and mice gnaw to reach sources of food and drink and to keep their teeth short. Their incisor teeth are so strong that rats have been known to gnaw through lead pipes and unhardened concrete, as well as sacks, wood and flexible packaging materials.

13.4 NUTRITIONAL CHANGES IN FOOD QUALITY

The four major factors, which bring nutritional changes in food quality, are light, oxygen, temperature and water activity. However, because of the diverse nature of the various nutrients as well as the chemical heterogeneity within each class of compounds and the complex interactions of the above variables, generalizations about nutrient degradation can not be made.

The major nutritional changes which occurred in foods are due to microbiological, enzymatic and chemical reactions.

Microbiological

- Growth or presence of toxicogenic and/or infective microorganisms.
- Growth of spoilage microorganism.

Enzymatic

- Hydrolytic reactions catalyzed by lipases, proteases, etc.
- Lipoxygenase activity.
- Enzymatic browning.

Chemical

- Oxidative rancidity.
- Oxidative and reductive discolouration.
- Non-enzymatic browning.
- Nutrient losses.

Physical

- Mass transfer, movement of low molecular weight components.
- Loss of crisp texture.
- Loss of flavours.
- Freeze-induced damaged.

One of the principal responsibilities of the food scientist is to preserve nutrients through all phases of food acquisition, processing, storage, and preparation. The key to doing this is a knowledge of the stability of nutrients under different conditions. Vitamin A is highly sensitive (i.e., unstable) to acid, air, light, and heat; on the other hand, vitamin C is stable in acid but is sensitive to alkalinity, air, light, and heat. Because of the instability of nutrients under various conditions and their water solubility, cooking losses of some essential nutrients may be greater than 75%. In modern food processing operations, however, losses seldom exceed 25%.

13.5 FOOD-BORNE DISEASE

Food-borne diseases cause food deterioration that may or may not alter a food's organoleptic properties but cause illness and disease to human beings after consumption. Food-borne diseases are classified as food infections or food intoxications. Food infections involve microorganisms present in the food at the time of consumption which then grow in the host and cause illness and disease. Food intoxications involve toxic substances produced in foods by microorganisms prior to consumption and cause disease upon ingestion. The toxin producer microorganisms need not to grow in the host to produce a disease or even be present in the food.

Staphylococcus aureus and *Clostridium botulinum* produce bacterial food poisoning by intoxication through the production of specific bacterial toxins. The toxin produced by *C. botulinum* is one of the most potent toxic substances known. Many bacteria can transmit food-borne infections capable of causing human disease. These include *Clostridium perfringens*, numerous members of the genus *Salmonella*, *Shigella dysenteriae, Vibrio parahaemolyticus, Streptococcus pyogens, Bacillus cereus, Campylobacter jejuni,* and other. A number of viral infection may also be contracted by man through contaminated food that has not been adequately processed or handled, including infectious hepatitis, poliomyelitis, and various respiratory and intestinal disorders. Over the last decade or so, several bacteria that had not been thought to be transmitted by food and cause human disease have found to do just that. Chief among these "newer" pathogens are *Aeromonas hydrophila*, *Yersinia enterocolitica*, *Listeria monocytogenes*, *Vibrio parahaemolyticus* and a particular type of *Escherichia coli* called 0157: H7 of particular importance is the recent discovery that some food-borne pathogenic bacteria can multiply at temperatures as low as 3.3^0C. This means that temperatures, which have been considered good for refrigerated storage, may not always keep food becoming a hazard.

Certain moulds produce mycotoxins, the best known being the aflatoxins by *Aspergillus flavus.* Aflatoxins are toxic to man and domestic animals. However, their carcinogenic properties are cause for much concern since aflatoxins can be produced in a wide range of cereals, legumes, nuts, and other products allowed to become mouldy. When such products occur in feeds, aflatoxins may subsequently be detected in the milk products of animals consuming the feed that is ultimately consumed by humans.

13.6 FOOD ALLERGIES

Food allergy may be defined as normal tissue reaction that may occur in some individuals after consuming a particular food or group of foods. Food allergens

consists mostly of proteins, though some other chemical compounds present in foods may also produce allergic reaction.

Since the allergen is carried through all parts of the body, the allergies manifestations are many and varied. The skin and mucous membranes are particularly sensitive to the allergen. The sign and symptoms of allergy may include (i) Skin lesions, rash and eczema; (ii) Nausea, vomiting, diarrhoea and colitis; (iii) Headache, cold and asthma, and (iv) Redness, swelling, burning and itching of the eyes and irritation of the nasal mucous membrane. The allergy associated with consumption of orange and tomato juices is apparently due to traces of proteins present in the juice or to the peel oil.

The allergies are treated by drugs and also different types of diets are used in treatment of allergy (i) Synthetic diets, (ii) Elimination diets, and (iii) Restricted diets. Desensitization of the subject to the allergic food may also be carried out. Currently the only way to treat food allergies is to avoid the food that triggers allergic reactions.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is shelf-life and dating of foods?

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2. Name the major causes of deterioration.

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3. What are nutritional changes in the food quality?

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4. Name the bacterial causal organism of food- borne infections.

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5. Food allergies consist of what bio molecules?

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13.7 ANTI-MICROBIAL AGENTS USED IN FOOD

Anti-microbial agents are the chemicals which inhibit the growth & development of bacteria, moulds and yeasts. They are weak acids work in the un-ionized form. They are not effective above their pKa values.

The use of anti-microbial agents depend on; **a**nti-microbial activity, pH of the food product, food composition, processing, and storage conditions, solubility, flavor, cost, marketing impact. The details of the most commonly used anti-microbial agents in food preservations are as follow:

13.7.1 Sulphite and Sulphur Dioxide

Sulphur dioxide and its derivatives have been extensively used in foods as a food preservative and anti-microbial agents. They act as an antioxidant, reducing & anti-microbial agents and prevents enzymatic, non-enzymatic reactions and microbial growth respectively. The common used forms are sulphur dioxide and sodium, potassium and calcium salts of sulphite, bisulfite or metabisulphite. The preservative action of sulphur dioxide as an anti-microbial agent in acid media, is due to undissociated compounds. It is like a biocidal and biostatic agent and is more active against bacteria than moulds and yeasts. It is more effective against Gram-negative bacteria.

13.7.2 Nitrite and Nitrate Salts

Nitrates and nitrites salts are inhibitors of toxic bacteria, involved in botulism, and considered as legal preservatives. Under regulations nitrites and nitrates are permitted as preservatives in cured meat and meat products including poultry at levels below 200 ppm. They also stabilize the colour after cooking and impart good flavour of lean meat without this the meat would be greeny brown. The use of nitrates and nitrites in the food industry is now subject to strict control.

13.7.3 Glycerol Esters

Glycerol esters show anti-microbial activity against Gram positive bacteria and yeasts. It is used as surface decontamination agents. It also inhibit *Clostridium botulinum* and widely applied in cured meats and refrigerated packaged fresh fish.

The inhibitory effect of the glyceride is due to the conduction of protons through the cell membrane, which effectively destroys the proton motive force that is needed for substrate transport. Death of cell arises due to the generation of holes in cell membranes.

13.7.4 Epoxides

Epoxides destroy all form of microorganisms, including spores and even viruses, but the mechanism of epoxides is poorly understood. They find applications in treating low moisture foods and to sterilize aseptic packaging materials. They are used in vapour state and after adequate exposure, most of residual unreacted epoxide is removed by flushing and evacuation.

13.7.5 p-Hydroxy Benzoate Alkyl Esters

The p-Hydroxy Benzoate Alkyl Esters (parabens) are widely used as anti-microbial agents in foods and pharmaceutical products particularly in baked foods, soft drinks, olives, pickles, jams and jellies and syrup. They are effective inhibitor of moulds and yeasts (0.5-0.1 %) but ineffective against bacteria, especially gram negative bacteria. In contrast to other *antimycotic* agents, the parabens are active at pH 7.0, and higher as they remain undissociated at these values.

Benzoates, sorbates, hydrogenperoxides, and propionates can also be used as anti-microbial agents.

13.8 ENZYME INACTIVATION

Some enzymes catalyze or initiate undesirable changes in colour, texture, flavour and nutrients of fruits and vegetables during storage and processing (Table 13.1). Inactivations of these enzymes prevent discoloration, improve flavour, soften tissues and loss of nutrients. Inactivation of enzymes is mainly done by blanching. Blanching is a mild treatment which expose plant tissues to steam or hot water, heating at 75-95 C for about 1 to 10 minutes, depending on the product requirements. At high temperature enzymatic proteins are denatured and make the enzymes inactive. If food processors did not blanch vegetables prior to freezing or dehydration, the natural enzymes would remain active even during frozen storage and destroy the product quality with time. Many vegetables which are not properly blanched develop a very noticeable off-odour and off-flavour.

Table 13.1: Enzymes responsible for quality deterioration in fruits and vegetables

Off-flavour development	• Lipoxygenase • Lipase • Protease
Texture changes	• Pectic enzymes • Cellulase
Colour changes	• Polyphenol oxidase • Chlorophyllase • Peroxidase (lesser extent) • Lipoxygenase*
Nutritional changes	• Ascorbic acid oxidase • Thiaminase

*hydroperoxides and radicals formed by lipid oxidation may destroy chlorophyll and carotenoids

In order to prevent undesirable changes in fruit texture, colour and flavour chemicals are used to inactivate enzymes as antioxidants. The inactivation of peroxidase is an indicator of effectiveness of blanching, and one could assume that all quality affecting enzymes had been destroyed.

13.9 TREATMENTS

The different treatments to prevent deterioration or spoilage of food should be performed so that it can be stored or preserved in fit conditions for future use. The classification of treatments of reducing deterioration is difficult because they do not act in isolation but take place together or one after the other. However the preservation procedures have two main characteristics:

- some of them are applied only to one or some categories of foods; others can be used across the board and thus a wider application (cold storage, freezing, drying/dehydration, sterilization, etc.);
- some guarantee food preservation on their own while others require combination with other procedures, either as principal or as auxiliary processes in order to assure preservation (for example smoking has to be preceded by salting).

13.9.1 Physical

It is better if the following physical treatments are kept in mind to control the spoilage.

- Heating,
- Cooling,
- Lowering of water content,
- Drying/dehydration,
- Concentration,
- Irradiation,

- Other physical means (high pressure, vacuum, inert gases),
- Salting.

13.9.2 Thermal

Heat or thermal processing includes heating and cooking, required to eliminate the potential of food borne illness. The simple act of cooking, frying, boiling or simply heating food prior to consumption are forms of food preservation. Cooked food itself can be held for several days provided it is protected from recontamination. Various methods in thermal processing include blanching, pasteurization and sterilization.

Blanching: Dipping of fruits & vegetables in boiling water or steam at temperatures around 75-95^{0}C for about 1 to 10 min, depending on the product requirements to inactivate enzymatic and biological activities. It is a necessary pre-treatment to achieve satisfactory quality in dehydrated, canned and frozen products. The process is required for reduction in enzyme activity otherwise undesirable changes in odour, flavour, colour, texture and nutritive value will occur during storage. It also helps in removal of intercellular gases to reduce the oxidative changes in food. Blanching may also result in some reduction in the microbial load and the texture may be improved.

Pasteurization: The food is heated to a temperature around 60 to 80 ^{0}C depending upon food product. The normal range is 65-75 ^{0}C at which nearly all the enzymes and vegetative microorganisms are inactivated. The heating may be done by steam, hot water, dry heat or electric currents, and then products are cooled promptly. Pasteurization does not kill all the microorganisms present in fruit juices. Some spores and spore forming bacteria like *Bacillus subtilis* can survive and multiply later.

Sterilization: Sterilization involves the use of heat at a temperature of 121°C (wet heat) for 15 min or longer to ensure total destruction of microorganisms including spores. The sterilized food must be placed in a container to prevent the entry of spoilage organisms. This is generally done with steam under pressure, as in a autoclave or commercial retort. Commercial pressure retorts operate at temperatures and for time intervals adequate to destroy large numbers of highly resistant bacterial spores within the canned food. Sterilization is not always necessary to kill all microorganisms but may be employed to destroy disease-producing organisms in the food.

13.9.3 Chemicals

Many chemicals will kill or inhibit the growth of specific microorganisms and prevent the deterioration of foods, but most of these are not permitted. A few that are permitted, in prescribed low levels in certain foods, include sodium chloride, acetic acid, sodium benzoate, sorbic acid, sodium, and calcium propionate, ethyl formate, and sulfur dioxide.

Sodium chloride: Common salt used in high concentration (15-20%) prevents the growth of microorganisms and increase the keeping quality of foods such as pickles. Salt at high concentration dehydrates microbial cells. Salt inhibits enzymatic browning and also acts as an antioxidant. Salt ionizes to yield chloride ions which, are harmful to the organisms and it also sensitizes the cell against carbon dioxide. Effectiveness of salt varies with its concentration and temperature.

Acetic acid: Acidic pH inhibits the growth of many microorganisms. Vinegar or acetic acid has germicidal and antiseptic properties and also checks aerobic and anaerobic fermentation. It is more effective against yeast and bacteria than molds. About 2% acetic acid prevents the spoilage of most products. It is used in preservation of pickles, sauces and chutney.

Citric acid: It is used in preservation of certain fruits and vegetables. It is added to jams, jellies, preserves and squashes. It increases the acidity and prevents mould growth.

Propionates: Sodium or calcium propionate is used most extensively in the prevention of mould growth. These are effective against moulds with little or no inhibition of most yeast and bacteria. Their effectiveness decreases with an increase in pH and optimal pH is 5 to 6, depending upon the food item. These are ideal preservatives for bread and baked foods to prevent contamination of loaves during slicing and/or wrapping.

Benzoic acid and its salt: Sodium benzoate as a salt of benzoic acid is used because it is more soluble than acid. It is benzoic acid molecule, which is germicidal. It is more effective against yeasts than molds. 0.06-0.10% of sodium benzoate preserves most fruit products (pH 3.5-4.0). In the long run, the benzoate may darken the products therefore, it is mostly used in coloured products of tomato, plum, watermelon, *jamun,* pomegranate and coloured grapes.

Sulphurous acid and its salts: Mostly potassium or sodium metabisulphite is used and gives characteristic sulpher dioxide smell. Sulphur dioxide retards oxidation, prevents discolouration or loss of flavour and vitamin C. It acts as a better preservative against bacterial fermentation and molds. It prevents enzymatic darkening of cut and peeled fruits and vegetables. But it cannot be used in products stored in tin cans because it causes pin holes in metals and forms incrustation of tin sulphide.

In dehydration of fruits and vegetables, burning of sulphur at levels 1000-3000 ppm preserves colour, as well as vitamin C, repels insects and destroys organisms. It bleaches colour of pigments and its use is restricted to products of fruit like mango, litchi, lime, orange, lemon, guava, etc.

Sorbic acid: It is an organic acid having anti-microbial properties and prevents moulds in preserves. The effectiveness of sorbic acid increases in acid media (pH < 6.0) and inhibit moulds, yeasts and some bacteria.

The sodium and potassium salts of sorbic acid are used as fungistatic agents for foods especially on surface and in wrapping materials. These are also used for the preservation of cheese, sweet pickles, etc. for the control of lactic acid fermentation.

Antibiotics: An antibiotic is a chemical produced by microorganism which, inhibit growth or destroy microorganisms. Antibiotics, subtelin and nisin are produced by *Bacillus subtilis and Streptococcus lactis* respectively and used to preserve asparagus, corn , peas, mushrooms, tomatoes and milk. They are more commonly used in canning of processed products and effectively reduce the thermal process requirements necessary to control the spoilage food products.

Chemicals preservations: Antioxidants, butylated hydroxy toluene (BHT) and butylated hydroxyanisole (BHA) are used as food preservative and they inhibit, retard or arrest the growth of microorganisms.

13.9.4 High Pressure Technology

High-pressure technology (HPT) is a new non-thermal process for preservation of fruits and vegetables. This technology is a combination of a high pressure, temperature and time. The process subjects food products to pressures between 50 and 700+ Mpa. High pressures kill microorganisms and inactivate enzymes without the use of heat that can damage the taste, texture, and nutritional value of the food. The mechanism does not promote the formation of new chemicals, "radiolytic" by-products, or free-radicals. By HPT, colour, nutrients, vitamins, and flavour are unchanged and undegraded. Moisture content of fruits and vegetables is very important because very little effect is obtained below 40%. Texture frequently can also be retained but will depend on the initial structure. The texture of high air content foods will likely be changed by HPT.

HPT is applied for the production of high quality shelf stable low acid foods. When combined with a moderate starting (pre-compression) temperatures of 70 to 95^{0}C, spoilage and pathogenic spores are destroyed within less than 1 to 2 minutes. Factors which are important to HPT are process pressure, process temperature (-20^{0}C to 121^{0}C), water activity, and pH.

Fruit based products such as jams, jellies, purees, sauces, fruit juices are processed in HPT at varying pressures 50-700 Mpa, temperature 5-20^{0}C and duration of 2-30 minutes and it improve gelation, faster sugar penetration and reduce the loss of flavour, texture, colour and aroma and nutrients. Inactivate pectinmethylesterase, polypenoloxidase, peroxidase and lipoxygenase and pathogenic microorganism activity also. Other advantages include: reduced process times, minimal heat damage problems, retention of freshness, flavour, texture and colour and no loss of vitamin C

13.9.5 Cooling

Cooling means storage temperature above freezing and it ranges from 16C to –2.2 C. Cooling will preserve perishable fruits and vegetable for days or weeks depending upon the nature of the food by retarding microbial growth and enzyme reactions at low temperatures. The lower the temperature, the greater the retardation. Various types of cool storage are available.

Cool storage: The temperature in cool rooms where surplus food is stored is usually around 15C. Enzymatic & microbial changes in the foods are not prevented but slowed down considerably. Root crops, potatoes, onions, apples and similar foods can be stored for limited periods.

Cold store or chilling (0 to 5^{0}C): Chilling temperatures are obtained by mechanical refrigeration. Fruits, vegetables and their products can be preserved for a few days to many weeks. The best storage temperature for many foods is slightly above 0^{0}C but this varies with the product. Besides temperature, the relative humidity can affect the preservation of the food. Commercial cold storages (temp.2-5^{0}C; R.H 90-100%) with automatic control of temperature are used for storage of semi-perishable foods such as potatoes and apples and made their availability throughout the year. The growth of bacteria, yeasts, and moulds, and rate of all chemical reactions is slow at or below 10^{0}C, and becomes slower the colder it gets.

13.9.6 Freezing

At temperature below the freezing point of water (–18 to –40^{0}C), growth of microorganisms and enzyme activity are reduced to minimum. Most perishable foods can be preserved for several months if the temperature is brought down quickly and the food is kept at these temperatures. Foods can be quickly frozen in about 90 minutes or less. Quick frozen foods maintain their quality and freshness when they are thawed. Frozen foods should, always be kept at temperatures, below –5^{0}C. Properly frozen (–12 to –17C^0 by excluding air), juice retains its freshness, colour and aroma for a long time.

13.9.7 Microwave

Microwave energy produces heat in materials that absorb and heat foods in a unique fashion that largely eliminate temperature gradients between the surface and centre of food masses. Foods do not heat from the outside to the inside as with conventional heating since microwave penetration can generate heat throughout the food mass simultaneously. The microwaves can result in very rapid heating but requires special equipment, packaging materials, since microwaves will not pass through metal cans or metal foils. Microwave heating produce major differences in food appearance and other properties compared to conventional heating and reduces process time by 90%. Microwave heating increases the temperature of the interior water parts of the solid and has the following advantages: (1) A penetrating quality that leads to uniform drying. (2) Selective absorption by liquid water, which leads to uniform moisture profile within the particle. (3) Ease to control due to rapid response of such heating.

13.9.8 IQF (Individual Quick Freezing)

IQF generally refers to freezing of solid food/pieces/grains like green peas, cut beans, cauliflower pieces, meat, fish etc. While quick freezing relates mostly to liquid, pulpy or semi liquid products like fruit juices, mango/papaya concentrate and purees etc. There is no clumping together of pieces or grains. They remain individual separate pieces. Individual quick freezing have advantages:

- Smaller ice crystals are formed, hence, there is less mechanical destruction of intact cells of the food.
- More rapid prevention of microbial growth.
- More rapid slowing down of enzymatic action.

13.9.9 Ohmic Heating

Ohmic heating, has the advantage that a product containing liquid, solid, or solid-liquid mixtures can, be heated rapidly with a uniform thermal profile. This ensures significant quality retention in comparison to conventional thermal processing, where heat transfer to the interior resulting in significant quality loss. Ohmic heating eliminate bacterial spores. In ohmic heating, the food should possess at least a slight electrical conductivity. Since fats and oils do not conduct electricity, ohmic heating cannot be used in these products.

In transit, ohmic heating could be used to heat the food. The system is light weight, requires minimum space and an electrical power supply, and food packages that can be accommodated between electrodes. It is also suited to the

available energy sources (electricity) in transit. This technology is used for simple heating of foods particularly which consists of particles suspended in liquids such as soups.

13.9.10 Drying and Dehydration

Both the terms "drying" and "dehydration" mean the removal of water. Drying is generally done under the influence of non-conventional energy sources like sun and wind. In sun drying, there is no temperature and humidity control. The hottest days are chosen so that the foods dry very fast, thus, preventing from getting spoiled due to souring. Quick removal of the moisture prevents the growth of the microorganisms. Dehydration means the removal of moisture by the application of artificial heat under controlled conditions temperature, humidity and airflow. In this process a single layer of fruit or vegetable, whole or slices is spread on trays, placed inside the dehydrator. The initial temperature of the dehydrator is usually 43°C which is gradually increased to 60-71 °C. Drying is economical and very useful process. Most of the foods contain enough moisture, which encourages action by their own enzymes and microorganisms growth.

Food dehydration cause minimum or ideally no other changes in the food properties and dried to final moisture of about 1-5%. Examples are dried milk and eggs, potatoes flakes, instant coffee, and orange juice crystals. Such products will have storage stability at room temperature for a year or longer. A major criterion of the quality of dehydrated foods is that when reconstituted by the addition of water they are virtually indistinguishable from the original food materials used in their preparation.

13.9.11 Irradiation

Irradiation is a non-thermal technology and involves the use of gamma rays, X-rays or electrons, and uses energy levels that assure no induction of radioactivity in the irradiated product. It retards ripening or senescence of raw fruits and vegetables, sprouting of potatoes. Irradiation will increase the shelf life of foods from 2-5 years. The product must be frozen to achieve stability without major off-flavours. A wide range of products can be preserved by irradiation but primarily it is used to preserve meats. Microorganisms are inactivated by different kinds of radiations. X-rays, microwaves, ultraviolet light, and ionizing radiations, differing in wavelength and energy have been used to preserve food. For all types of radiation, the doses required to sterilize foods, and inactivate enzymes, are generally excessive or borderline from the food quality view point, and all may cause flavour, colour, texture, or nutritional defects. Doses less than sterilizing appear more generally useful to extend storage life. Sub-sterilization doses can inactivate enzymes responsible for initiating vegetable sprouting.

Today, foods are irradiated with ionizing radiation, obtained from radioactive isotopes, which does not rise the temperature significantly and called "cold sterilization". Several foods such as spices, vegetables and fruits, and poultry have been approved for irradiation pasteurization at specific doses in India.

13.9.12 Curing

Curing is a formation of multilayered protective periderm on tuber vegetables after harvest when kept in heaps for 15 to 20 days at ambient conditions to

prevent bruising during transport and handling, entry of microorganism and excessive loss of moisture. Plant tissues are covered with protective tissues, which serve to protect the plant from excessive water loss. The primary protective layer is the epidermis but if the plant organ undergoes secondary growth, a multilayered periderm may develop, for example, on apples or potatoes. The epidermis is covered with a waxy cuticle of cutin while the cell walls of periderm tissues generally become impregnated with suberin. Both cutin and suberin can reduce water losses from plant surfaces; however some water loss is inevitable.

13.9.13 Smoking

Smoke is used for preserving foods such as meats and fish. The preservative action generally comes from a combination of factors. Smoke contains preservative chemicals such as small amounts of formaldehyde and other materials from the burning of wood. In addition, smoke generally is associated with heat, which helps to kill microorganisms. This heat also tends to dry out the food, which further contributes to preservation. Smoking over a fire may be quite effective in preserving certain foods; on the other hand, today smoke may be added merely to flavour food, that is, without heat from burning. In meat products, smoke combined with other preservatives is used more for its flavour than for its preservative action.

13.10 HYGIENE AND SANITATION

'Hygiene' describes a system of sanitary principles for the preservation of health. Food hygiene is much more than cleanliness, it involves all measures to ensure the safety, soundness and wholesomeness of food at all stages from its production, processing, manufacturing, packaging, storage, distribution, display for sale and consumption. Food hygiene aims for the production, preparation processing and presentation of food, which is safe for consumer and had good keeping quality. It covers not only the proper handling of foodstuff but also cleanness and sanitization of all the utensils and apparatus used in preparation, premises of food processing unit, service and consumption to eliminate the contamination of food borne microorganism.

The food hygienic measures will involve:

- Protecting food from risk of contamination of any kind.
- Preventing any organisms multiplying to an extent which would expose consumers to risk, or result in premature decomposition of food.
- Destroying any harmful bacteria in the food through cooking or processing.

High standards of food hygiene are essential to prevent food poisoning, food-borne infections, food spoilage, loss of productivity, loss of business, food losses due to premature spoilage or damage, incorrect storage temperature or pest infestations and prosecutions for contraventions of food legislation. Hence, these standards of food must be achieved at a reasonable cost to ensure that the business remains profitable. For it, cost effective hygiene may be considered.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are anti-microbial agents and write their names?

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2. What is the enzyme inactivation and write the names of enzymes involved in colour changes of foods?

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3. Write different treatments to preserve the foods.

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4. Describe the benefits of hygiene and sanitation.

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13.11 LET US SUM UP

Deterioration of food is a decay or undesirable decomposition of constituents by excessive growth of microorganism or by other physical and chemical causes. The deterioration factors are: (1) growth and activities of microorganisms, principally bacteria, yeast, and moulds; (2) activities of food enzymes and other chemical reactions within food itself; (3) infestation by insects, parasites, and rodents; (4) inappropriate temperatures; (5) gain or loss of moisture; (6) oxygen (7) light (8) physical stress and (9) time. Biochemical reactions in foods are catalysed by enzymes and are responsible for undesirable or desirable changes. **N**utritional changes occur in foods during storage and processing due to microbiological, enzymatic and chemical reactions**.** Food-borne diseases cause illness and infections to humans after consumption contaminated foods. Anti- microbial agents are the chemicals which inhibits the growth & development of bacteria, moulds and yeasts. At high temperature enzymatic proteins are denatured and make the enzymes inactive. Different treatments such as thermal, chemicals, high pressure technology, cooling, freezing, microwave, individual quick freezing, ohmic heating, drying and dehydration, irradiation and smoking are done to prevent deterioration or spoilage of food so that it can be stored or preserved in fit conditions for future use. Food hygiene involves all measures to ensure the safety, soundness and wholesomeness of food at all stages: production, processing, manufacturing, packaging, storage, distribution, display for sale and consumption.

13.12 KEY WORDS

Anti-microbial agents : Chemicals, which inhibits the growth and development of microorganisms.

Bacteria : They are minute unicellular microorganisms**.**

Biochemical reactions : Reactions catalysed by the enzymes in food and plant issues.

Blanching : Dipping of fruits and vegetables in boiling water or exposing these to steam for a few minutes to kill enzymatic and biological activity.

Cooling : Use of low temperature to retard chemical reaction and action of enzymes.

Drying and dehydration : Removal of water.

Enzyme inactivation : Stoppage of enzyme activity by denaturing them

Food-borne disease : Disease or infection caused to humans after eating spoiled food

Food deterioration : Decay or undesirable decomposition of food.

Freezing : At temperature below the freezing point of water (−18 to −40° C) growth of microorganism and enzymes activity are reduced to a minimum.

High pressure technology	:	It is a non-thermal process for preservation of foods.
Hygiene	:	A system of sanitary principles for preservation of health.
Individual quick freezing	:	Means individual freezing of solid food/ pieces.
Irradiation	:	Exposure to radiation-generally used to sterilize various foods by killing microorganisms.
Microorganisms	:	Very small living beings such as bacteria, yeast and fungi.
Pasteurization	:	The process of killing harmful organisms in a food by heating at controlled temperature below 100°C.
Sterilization	:	Heating at high temperature i.e. 100°C to kill microorganisms.

13.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Shelf life is the time required for a food to reach at unacceptable stage.
   - The retail package of processed foods should have date of manufacture and expiry date to know the self-life.
2. Your answer should include the following points:
   - Microorganism, bacteria, yeast, moulds.
   - Activities of enzymes.
   - Chemical reactions.
   - Moisture, temperature, oxygen.
3. Your answer should include the following points:
   - Enzymatic: lipases, proteases, lipoxygenase, enzymic browning.
   - Chemical: Rancidity and non-enzymatic browning.
   - Physical: loss of texture and flavour.

4. Your answer should include the following points:
   - Clostridoium
   - Salmonella
   - Shigella
5. Your answer should include the following points:
   - Proteins
   - Chemicals

Check Your Progress Exercise 2

1. Your answer should include the following points
   - Anti-microbial agents are the chemicals which inhibits the growth & development of microorganism.
   - Weak acids and work when in the un-ionized form.
   - Sulphur dioxide and its derivatives, Nitrates and nitrites salts, Glycerol esters, Epoxides, p-Hydroxy Benzoate Alkyl Esters (parabens).
2. Your answer should include the following points:
   - Denaturation of enzymic proteins.
   - Blanching.
   - Polyphenoxidase and peroxidase.
3. Your answer should include the following points:
   - Thermal, ohemic heating.
   - Chemical.
   - Cooling, freezing, individual quick freezing.
   - Microwave, irradiation.
   - Smoking.
   - Drying.
4. Your answer should include the following points:
   - Reduction of microorganism contamination.
   - Prevention of food spoilage or decomposition.

13.14 SOME USEFUL BOOKS

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3. Potter, N.N. and Hotchkiss, J.H. (1996) Food Science (5th Ed). CBS publishers and Distributors, New Delhi.
4. Srivastava, R.P. and Kumar Sanjeev (2nd Edn) (1998) Fruit and vegetables preservation: Principles and Practices. International Books Distributing Co., Lucknow, India
5. Verma, L.R. and Joshi. V.K. (2000) Post-harvest Technology of fruits and vegetables. Indus Publishing Company, New Delhi.
6. Wills, R.B.H., Mc Glasson, W.B., D. Graham Lecture, T.H. and Hall, E.G. (1989) Post-harvest: An Introduction to the physiology and handling of fruits and vegetable. Chapman and Hall, Inc, New York.