

Introduction

- Healthy tissues inside foods and foods in their natural form resist infection and they do not harbour microorganisms.
- On the other hand, spoilage **of highly perishable foods is natural**. The onset of food spoilage is rather indefinite.
- It is a gradual process occurring because of **poor sanitation, enzymatic or chemical reactions, improper temperature controls, microbial growth or physical abuse starting from the time food is harvested, slaughtered or manufactured till it is consumed**.
- Physical changes, such as **bruising or puncturing of tissue and water loss** and
- chemical changes, such as those **caused by enzymes**; or the effects of microbial growth can make food unappealing.
- Foods undergo undesirable changes in the physical and chemical characteristics of food ultimately leading to spoilage of food. In general, food spoilage is a state in which food is deprived of its good or effective qualities.
- Spoilage of food refers to the undesirable alterations in foods or the food undergoes some physiological, chemical and biological changes, which renders it inedible or hazardous to eat.
- In extreme cases, the food becomes totally unpalatable and unfit for human consumption. Hence, it is essential to process or preserve foods after it is harvested or slaughtered to combat the problem of food spoilage.

Undesirable Changes in Food due to Spoilage

Food deterioration is manifested by the reduction in aroma, flavour, textural and nutritional values of foods. Different types of undesirable changes which occur due to spoilage in food are listed as follows:

- **Change in colour:** The fruits like **bananas and apples** turn black after storing for a long period of time and reduce the acceptability of food.
- **Change in smell:** Rancid smell of spoiled oils and fats, **bitter smell of curd** or **sour smell of starchy food**.
- **Change in consistency:** Splitting of milk, curdling of milk, stickiness and undesirable viscosity in spoiled cooked dal and curries and spoiled cooked vegetables.
- **Change in texture:** Some vegetables like potato, brinjal and carrot undergo too much softening leading to rotting.
- **Change due to mechanical damage:** Mechanical damages such as eggs with broken shells, mechanical spoilage of fruits and vegetables during transportation also constitute food spoilage.

Factors Affecting food Spoilage

The types of spoilage of a particular food item depend to a great extent on the following:

The composition of food:

The **composition of food influences its susceptibility to spoilage**. For example- presence of proteins and carbohydrates especially sugars are preferred by microorganisms for energy source. Very few utilize fat for energy production.

Structure of the food item:

Whole healthy tissues of food from inside are sterile or low in microbial content. Skin, rind or shell on food works as its protective covering from spoilage microorganisms.

Types of microorganisms involved:

The types of microorganisms present in food depend on its composition of food.

Conditions of storage of the food:

Conditions of storage of food affect the growth of microorganisms. Even if the proper storage of food is done, the food loses its freshness and nutritive value if it is stored for too long.

Classification of Foods by ease of Spoilage

Foods are classified into three groups based on ease of their spoilage.

- **Relatively stable or non-perishable foods:** Foods that do not spoil unless handled carefully. E.g. grains, flour, sugar, pulses etc.
- **Protectable or semi-perishable foods:** Foods those remain unspoiled for a fairly long period if properly handled and stored. E.g. potatoes, apples, onions etc.
- **Perishable foods:** Foods that spoil readily unless special preservative methods are used. E.g. milk, eggs, meat, fish, poultry, most fruits and vegetables.

Causes of Food Spoilage

There are mainly three types of causes of food spoilage viz. biological, chemical and physical causes. Biological causes comprise of growth and activity of microorganisms such as [bacteria](#), yeast and [moulds](#); activity of food enzymes and damage due to pests, insects and rodents etc. Chemical causes include reaction with oxygen and light and chemical reactions within food constituents. Physical causes consist of temperature and physical abuse.

All of these factors can act together. For example, [bacteria](#), insects, and light, all can be operating concurrently to spoil food in a field or in a warehouse. Similarly, heat, moisture, and air at the same time affect the multiplication and activities of [bacteria](#) and chemical activities of food enzymes.

The major types of spoilage that occur in foods are due to microbiological, biochemical, physical and chemical changes. These include:

§Growth and activity of microorganisms such as [bacteria](#), yeast and [moulds](#)

§Activities of food enzymes, present in all raw foods, promote chemical reactions within the food affecting especially the food colour, texture and flavour

§Inappropriate holding temperatures (heat and cold) for a given food

§Gain or loss of moisture

§Reaction with oxygen and light causing rancidity and colour changes due to oxidative reactions

§Physical stress or abuse

§Damage due to pests, insects and rodents etc.

§Non-enzymatic reactions in food such as oxidation and mechanical damage

Spoilage due to growth and activity of microorganisms:

Most significant deteriorative changes occur in foods due to microorganisms present in air, soil, water and on foods. They use our food supply as a source of nutrients for their own growth, which results in deterioration of food and render our food supply unfit for consumption. Microbes spoil any food in many ways viz. by increasing their number; by utilizing nutrients; by producing enzymatic changes; by contributing off-flavours; by breakdown of a product; and by synthesis of new compounds.

The three major types of microorganisms which cause food spoilage are bacteria, yeasts and moulds.

- Bacteria

- Yeasts

- Moulds

- Factors affecting growth of microorganisms

- Spoilage due to enzymatic activity

- Factors affecting enzymatic activity

- Spoilage due to insects, pests and rodents

- Spoilage due to chemical reactions

- Spoilage due to physical factors

Bacteria

Bacteria are ubiquitous, minute unicellular microorganisms and cannot be seen with naked eye. The growth of bacteria depends upon specific kind of food, temperature, pH, moisture and oxygen. Bacteria are much more difficult to kill than [moulds](#) and yeast and are the most common [causes of food spoilage](#). They are present in two forms viz. vegetative and spore, which are active and resting form, respectively. The vegetative forms of bacteria are easily destroyed at boiling temperature whereas spores require harsh treatments like application of heat (100°C) for a long time (six hours) or at 121°C under 15 psi pressure for 30 min.

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](#). Most bacteria grow best at neutral pH, however, few bacteria also grow in acid or alkaline media. 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 100°C whereas low acid foods such as corn, peas, beans and all vegetables except tomatoes have to be processed at higher temperature (116°C) in a steam pressure to kill bacteria. 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 are classified as aerobic, anaerobic and facultative when they require free oxygen for growth, no oxygen and can grow with or without free oxygen, respectively. On the basis of temperature required for growth, bacteria can be grouped into four types viz. mesophiles, obligate thermophiles, facultative thermophiles and psychrophiles requiring temperature below 38°C, 38 to 82°C, below 38 to 82°C and at refrigeration temperatures, respectively.

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.

Some bacteria are also useful particularly in food processing. For example- aerobic bacteria like Acetobacter aceti used in vinegar production and lactic acid bacteria like Lactobacillus plantarum, Pediococcus cerevisiae, Leuconostoc mesenteroides etc. produce lactic acid by [fermentation](#) of carbohydrates.

Yeasts

Yeasts are microscopic unicellular fungi, which are non-motile round or elliptical. Yeasts are larger than [bacteria](#) in size. Yeasts reproduce by the process of “budding” and therefore known as true yeast. 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 sugar solution of low concentration. Most of the yeasts usually do not grow in media containing more than 65 per cent of sugar or 0.5 per cent acetic acid. Heating at 60°C for a few minutes is sufficient to destroy most species of yeasts. Boiling destroys yeast cells and spores effectively.

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, sherbet, honey etc. and spoil the appearance, taste, texture and wholesomeness of fruits and fruit products. During active [fermentation](#), yeast can be recognized by formation of bubbles of carbon dioxide gas on the surface of the product. Some of yeasts which grow on fruits are Saccharomyces, Candida etc. Saccharomyces generally spoils low sugar products whereas Candida is responsible for spoilage of high acid foods, salty foods and butter etc.

Some yeasts which are like true yeast but do not form spores are known as pseudo-yeasts. This type of yeast is not

Moulds

Moulds are multicellular filamentous fungi. They grow on foods with their fuzzy or cottony appearance, sometimes coloured. 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. Some of common moulds are *Aspergillus*, *Penicillium*, *Rhizopus* and *Helminthosporium*. Usually a moldy or mildewed food is considered unfit to eat.

They thrive best in closed, damp and dark situation and require adequate supply of warmth, moisture and air for growth. They are strictly aerobic in nature and require less available moisture than yeast and [bacteria](#) and can grow well at 25-30°C. Moulds prefer sugar containing substances like jam, jelly, preserves and other sweet 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 . 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.

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 product. Some moulds produce toxic substances known as mycotoxins. For example *Aspergillus flavus* produces aflatoxins in moist groundnuts.

Factors Affecting Growth of Microorganisms

Growth of microbes and their propagation in the food is one of the important factors to food spoilage. They decrease the nutritive value and wholesomeness of food. Hence, the knowledge of the factors that favour or inhibit growth of microorganisms is essential to an understanding of the principles of food spoilage or preservation. The various factors that affect the growth of microbes are given as follows:

§Nutrients and other constituents in food:

Nutrients in food, their kinds and proportions, are all important in determining what organism is most likely to grow. Proteins are degraded by the proteolytic enzymes present in aerobic and anaerobic microbes like [bacteria](#) and [moulds](#). The aerobic degradation does not result into objectionable products, but anaerobic degradation of protein may result into awful odour and is called putrefaction. Smell of hydrogen sulphide (H₂S) and ammonia (NH₃) is common during putrefaction.

Carbohydrates are the most preferred nutrients for microbial growth and are affected primarily by yeast and [moulds](#). Microbes degrade carbohydrates in food resulting in the production of alcohol, lactic acid, acetic acid, propionic acid, butyric acid etc.

§Microbes break down fats in food resulting in the production of fatty acids and glycerol. Fats are mainly digested by [moulds](#) and few gram negative [bacteria](#).

Organic acids are mostly present as salts in food. These are oxidized to carbonates by the microbes making the food alkaline.

§Acidity:

Foods having pH below 4.5 and above 4.5 are classified as acidic and non-acidic foods, respectively. Acidic foods are mainly spoiled by [moulds](#) and [yeasts](#) whereas the non-acidic foods are particularly attacked by bacterial spoilage.

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§Water content:

Microbes require at least 13 per cent free water for their growth and it is best expressed in terms of available water or water activity (aw). The aw of pure water is 1.0 and many [bacteria](#), [yeasts](#) and [moulds](#) require 0.91, 0.88 and 0.80 aw, respectively. Foods preserved with salt or sugar concentration do not support growth of most microbes. For example salt concentration of 5-15 per cent inhibits growth of [bacteria](#) whereas many [moulds](#) and some [yeasts](#) can tolerate more than 15 per cent. Sugar concentration of 65 per cent and above is required to inhibit mould growth whereas 50 per cent do not allow [bacteria](#) and most [yeasts](#).

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§Physical and environmental factors:

Temperature of food affects the growth of microbes. Temperature in the range 20-50°C is most suitable for the growth of microbes. Most of the bacterial pathogens of fruits and vegetables will grow between 6 and 35°C. Some fungi (Botrytis cinerea) will survive and even grow at low temperatures, 1°C, on agricultural produce, whereas Botryodiplodia theobromae or Aspergillus niger cause losses in warm regions.

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§Availability of oxygen:

Anaerobic micro-organisms are mainly involved in the spoilage of air tight canned food under anaerobic conditions. Oxygen is necessary for mould growth.

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§Presence of inhibitory substances:

Inhibitory substances originally present in food, added purposely or accidentally or developed thereby prevent growth of microorganisms.

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§Biological structure:

The biological structure of food has a protective function against food spoilage. The inner parts of whole, healthy tissues of living plants and animals are either sterile or low in microbial content. An increase in exposed surface due to peeling, skinning, chopping or mincing distributes spoilage.

Spoilage due to Enzymatic Activity

Enzymes are complex chemical substances, which are present in all living organisms and tissues, which control essential metabolic processes. Different biochemical reactions in foods and plants tissues are catalysed by enzymes. Enzymatic spoilage is the greatest cause of food deterioration. They are responsible for certain undesirable or desirable changes in fruits, vegetables and other foods. Examples involving endogenous enzymes include:

§the post-harvest senescence and spoilage of fruit and vegetables;

§oxidation of phenols in plant tissues to orthoquinones by phenolases, peroxidases and polyphenol oxidases (PPO). These orthoquinones rapidly polymerize to form brown pigments known as melanin leading to enzymic browning;

§sugar – starch conversion in plant tissues by amylases;

§post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

If enzymatic reactions are uncontrolled, the off-odours, and off-colours may develop in foods.

Factors Affecting Enzymatic Activity

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

Enzymes can act between 0°C and 60°C but 37°C is optimum temperature. Enzymes can be permanently inactivated by heat. It has been seen that for each 10°C rise in temperature, the activity of microorganisms and enzymes increases by at least twice, in the range 0-60°C. Above this, heat quickly destroys enzymes and stops living cells from working. All enzymes are inactivated at 80°C. Decreased temperatures therefore work by slowing down these changes.

Spoilage Due to Insects, Pests and Rodents

The main categories of foods subject to insects and pest attack are fruits, vegetables, grains and their processed products. Warm humid environment promote insect growth, although most insects will not breed if the temperature exceeds above 35°C or falls below 10°C. Many insects cannot reproduce satisfactorily unless the moisture content of their food is greater than 11 per cent.

The presence of insects and pests and their excreta in foods may render consumable loss in the 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.

Rats and mice carry disease-producing microorganisms on their feet and/or in their feces and urine and contaminate the food by their presence.

Spoilage Due to 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, oxygen, 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, caramelization and ascorbic acid oxidation. Maillard reaction occurs due to reactions between reducing sugars and amino acids in the presence of heat and results in formation of black brown insoluble pigments . Caramelization of sugars occurs in presence of high heat and low moisture content in the food. Oxidation of fatty acids to other chemicals like aldehydes, ketones, alcohols and esters also results in off-flavours.

Spoilage Due to Physical Factors

Physical factors such as temperature, moisture and pressure can also cause food spoilage. 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 occurs. Freezer induced damage observed in frozen foods affects its quality . Anthocyanins, the pigment in fresh and processed foods, form complexes with metals resulting in the change in colour. E.g. Red sour cherries react with tin and form undesirable purple complex. Carotenoid, another colour pigment, degrades by oxidation in the presence oxygen, light and heat.

Effects of Spoilage on Nutritional Quality

Effect of spoilage on nutrient degradation cannot be generalized 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. The major nutritional changes which occur in foods due to microbiological, enzymatic and chemical reactions are listed in below Table.

Type of change	Nutritional quality related changes in food		
Microbiological	Growth or presence of toxicogenic and/or infective microorganisms		
Enzymatic	1. Hydrolytic reactions catalyzed by lipases, proteases, etc. 2. Lipoxygenase activity		
Chemical	1. Oxidative rancidity 2. Non-enzymatic browning 3. Nutrient losses Foods contaminated with microorganisms may cause food borne illness. Food borne illnesses can be classified as food infection and food intoxication. Food infection occurs due to growth of pathogenic microorganisms in victim's digestive tract causing diarrhea, vomiting, fever etc. For example- Salmonellosis due to consumption of Salmonella sp. contaminated food. Food intoxication or poisoning is caused due to ingestion of food containing toxic compounds produced by pathogenic microorganisms in food. E.g. Staphylococcus aureus and Clostridium botulinum causes food poisoning. Measures for the prevention of food spoilage: Manipulation of factors controlling the conditions required for microbial growth and enzyme action viz. temperature, moisture, air and pH other than the food itself can help prevent food spoilage.		

Introduction

Food preservation is one of the oldest technologies used by the mankind. The perishable foods like fruits, vegetables, milk, meat and fish etc. deteriorate or decay easily, so considerable amounts of such commodities are wasted in various stages of food supply chain unless special methods are applied for their preservation. Preservation of food involves the processes in which, the perishable food materials are given a suitable physical or chemical treatment to prevent their spoilage and to retain their nutritive value for long periods.

Principles of Food Preservation

All food preservation methods are based upon the general [principle](#) of preventing or retarding the causes of spoilage caused by microbial decomposition, enzymatic and non-enzymatic reaction, chemical or oxidative reactions and damage from mechanical causes, insects and rodents etc. Food preservation operates according to three principles, namely:

1.Prevention or delay of microbial decomposition brought out byKeeping out microorganisms or asepsis

2.Removal of microorganisms e.g. washing, filtration etc.

3.Hindering the growth and activity of microorganisms by controlling the conditions required for the growth and activity of microorganisms by use of low temperature, drying, maintenance of anaerobic conditions or chemicals

4.Killing microorganisms by heat or [irradiation](#)

5.Prevention or delay of self-decomposition of foods byDestroying or inactivating food enzymes e.g. [blanching](#), low temperature storage, chemical preservation, drying etc.

6.Preventing or delay of chemical reactions e.g. prevention of oxidation with the use of antioxidants as oxygen speeds up decomposition of food and antioxidants deprives food from oxygen.

•Prevention of damage because of external factors such as insects, rodents, dust, odour, fumes, and mechanical, fire, heat or water damage.

Eg. Use of boxes, cartons, and shock absorbing materials, sealed tight, vacuum-packaging etc.

[Methods of Food Preservation](#)

The different preservation methods commonly employed are as discussed below:

1. Asepsis

Food is a living system and in its natural form it has its own protective mechanisms. When the food is removed from the field or protective skin or peel, it begins to deteriorate. Asepsis is a process of keeping microorganisms out of food. An aseptic environment can be created by proper packaging of the product, which separates the internal environment from the surroundings.

2. Maintenance of general cleanliness and sanitary conditions while processing and handling the product from raw material to finished stage can help in preventing the entry of microorganisms into the product.

3. Removal of microorganisms

It is well known fact that microbes are everywhere. The dust and dirt adhering to the raw material contain microorganisms and by applying various pre-treatment/ cooking methods, number of microorganisms can be reduced considerably. Such steps include:

3. Washing

4. Trimming ingredients

5. Discarding dirt

6. Filtering

7. Centrifugation

8. Sedimentation

9. Maintenance of anaerobic conditions/ packaging

Packaging food in a vacuum environment, usually in an air-tight bag or bottle results in anaerobic environment. As [bacteria](#) need oxygen for survival, the vacuum environment in the package slows down the spoilage by them.

Drying Drying is one of the oldest and the simplest method of preserving food. It refers to removal of water from the food. Dried foods are preserved because the available moisture level is so low that the microorganisms cannot grow and the enzyme activity is also controlled. Drying can be accomplished by a number of methods viz. sun drying, mechanical/ artificial drying and freeze drying etc.

Dried foods are compact and lightweight; do not require refrigeration and last much longer than the fresh foods. Dried foods should be stored in airtight containers to prevent moisture from rehydrating them and allowing microbial growth. **Sun drying** Sun-drying takes heat from sun rays but it is a slow process involving risk of contamination and spoilage. The limitation for sun drying is availability of climate with a hot sun and a dry atmosphere.

10. Mechanical/ artificial drying

Dehydration process usually implies the use of controlled conditions of heating, with the forced circulation of air or artificial drying (mechanical drier) in contrast to sun drying. Using mechanical driers, fruits, fruit leathers, banana chips, tea, coffee, milk, soups, fish, meat, eggs and vegetables can all be dried year-round.

11. Freeze drying

Freeze-drying is a form of dehydration in which the product is first frozen and then water is removed under vacuum as vapour by sublimation. The [principle](#) behind freeze drying is that under certain conditions of low vapour pressure, water in the form ice evaporates as water vapour directly without turning into liquid phase. The advantage is that the food structure and nutritional properties are better conserved but the equipment and its maintenance is costly.

12. Smoking

Smoking has been used as a method of food preservation from time immemorial. In this method, foods are exposed to smoke by burning some special kinds of wood, which has two main purposes, adding desired flavouring and preserving. Smoke contains chemicals like formaldehyde, which is bactericidal. And also the dehydration occurring due to smoking is responsible for its preservative action. The smoke is obtained by burning wood like oak, maple, walnut and mahogany under low breeze/ wind. Most meat is smoked after curing to aid their preservation. Examples of smoke preserved foods are smoked beef, ham, bacon, fish and meat.

13. Food concentration

Relatively few liquid foods are preserved by concentration, involving preservative action of reduction in water activity (aw) and development of osmotic pressure, which retard the microbial growth and enzymatic reactions. Concentration of food is usually done for many reasons: reduction in volume and weight; reduction in packaging, storage and transport costs; better microbial stability; and convenience. Examples of food preserved by concentration are tomato paste, fruit juice concentrate, soup and condensed milk. The rate of heating should be controlled to prevent localized burning of the product, particularly when it has become thickened towards the end of boiling.

Use of high sugar or salt content Sugaring

A strong sugar solution (about 68 per cent or more) draws water from the microbial cells and thus, inhibits the growth of microbes. Examples of food preserved by high sugar concentrations are fruits in heavy sugar syrup (preserve or murraba), jams, jellies, marmalades, candies and sweetened condensed milk.

14. Pickling

Pickles are the relishing accompaniments in the Indian meals. Microorganisms do not grow well in acidic solutions. And this is the basis of preserving fruits and vegetables by pickling. Pickling uses the salt combined with the acid, such as acetic acid (vinegar). Some of the fruits and vegetables, which are generally pickled, are raw mangoes, limes, Indian gooseberry (aonla), ginger, turmeric and green chillies.

15. Salting or curing

Salting is being done in case of meat and fish preservation since ancient times. Curing preserves the food by drawing moisture from the meat through osmosis and makes it unavailable for microbial growth and enzyme action. Meat is generally cured with salt or sugar, or a combination of the two. Nitrates and nitrites are also often used to cure meat, which contribute the characteristic pink colour to meat, as well as inhibition of *Clostridium botulinum*. Dry salting is used in India for the preparation of preserved tamarind, raw mango, Indian gooseberry (aonla), fish and meat etc.

Use of organic acids Organic acids are used in food preservation because acid conditions inhibit growth of many spoilage microorganisms. [Bacteria](#) are generally pH sensitive. Organic acids penetrate the [bacteria](#) cell wall and disrupt its normal physiology and thus preserve the food. Acetic acid, lactic acid, citric acid and malic acid are widely used for preservation in food products.

Methods of Food Preservation

- [Fermentation](#)
- [Use of low temperatures](#)
- [Use of High temperatures](#)
- [Use of Chemical Preservatives](#)
- [Carbonation](#)
- [Irradiation](#)
- [Combination of two or more of the above methods or hurdle technology](#)

Fermentation

Fermentation involves multiplication of microorganisms and their metabolic activities are also encouraged, in contrast to other preservation methods. In this, microorganisms break down complex organic compounds into simpler substances either in aerobic or anaerobic conditions. The chemicals produced by the microorganisms such as alcohol or acids cause the preservative effect of fermentation by slowing down spoilage factors. The principal chemicals involved are the acids (especially lactic acid) and alcohol. These inhibit the growth of common pathogenic organisms in foods. Examples of food preserved by fermentation are alcoholic products (e.g., beer, fruit wine) and acid products (e.g., vinegar, pickled vegetables), yogurt, cheese etc. This technique is often combined with [pasteurization](#).

Use of low Temperatures

The metabolism of a living tissue is a function of the temperature of the environment. Low temperature is applied to retard chemical and enzymatic reactions in food. In addition, reducing temperature retards or stops growth and activity of microorganisms in the food. Lower the temperature, the slower will be the rate of above natural activities. Cooling thus slows down or stops the spoilage of foods. [Freezing](#) and refrigeration are among the oldest methods of preservation. Mechanical ammonia refrigeration systems invented during 1875 allowed development of commercial refrigerated warehousing and [freezing](#).

i.Low temperatures employed can be:Cellar storage temperature (15°C)
It is usually used for the storage of surplus foods like root crops, potatoes, onions, apples, etc. for limited periods.

ii.Refrigeration/ chilling temperature (0 to 5°C) Foods kept at this temperature slow down the microbial activities and chemical changes resulting in spoilage. Mechanical refrigerator or cold storage is used for this purpose. Examples of this include meats, poultry, eggs, fish, fresh milk and milk products, fruits, vegetables, etc. which can be preserved for 2-7 days by refrigeration.

iii.[Freezing](#) (-18 to -40°C)
In [freezing](#), water in food turns into ice and hence, makes the water unavailable for reactions to occur and for microorganisms to grow. Most perishable foods like poultry, meats, fish, ice-creams, peas, vegetables, juice concentrates, etc. can be preserved for several months at this temperature. In vegetables, enzyme action may still produce undesirable effects on flavour and texture during [freezing](#). Heating, like [blanching](#), therefore, must destroy the enzymes before the vegetables are frozen.

Use of High Temperatures

The process of heating was used centuries ago before its action was understood. Food is heated up or cooked. Heat is used to inactivate organisms or enzymes of spoilage significance in the foods. Microorganisms are killed by heat because the application of heat coagulates the food proteins and inactivates the microbial enzymes and thus results in death of microorganisms. The examples include all forms of cooked food, [pasteurization](#), milk sterilized by UHT (ultra high temperature), [canning](#) etc. One of the most important modern applications of the heat preservation is the [pasteurization](#) of milk.

i. Heat treatment of food may be given in different ways:

ii. [Pasteurization](#) (temperature below 100°C)

iii. [Pasteurization](#) is a heat treatment involving temperatures below 100°C that kills a part but not all the microorganisms present in food. Milk, for example, is usually heated to 63°C for 30 min or 71°C for 15 seconds or in UHT 138°C for 2-4 seconds.

iv. Examples include milk, wine, beer, fruit juices and aerated waters which are routinely pasteurized. The mode of heating can be steam, hot water, dry heat or electric currents.

v. The products are cooled promptly after the heat treatment. [Pasteurization](#) is usually supplemented by other methods to prolong shelf-life.

vi. Boiling (temperature at 100°C)

vii. Cooking of rice, vegetables, meat, fish etc. at home is usually done by boiling the food with water and involves a temperature around 100°C.

viii. [Canning](#) (temperature above 100°C)

ix. [Canning](#) is the process in which the foods are heated in hermetically sealed (airtight) jars or cans to a temperature that destroys microorganisms and inactivates enzymes that could be a health hazard or cause the food to spoil.

x. The vacuum seal formed after heating and cooling in the process ensures that no microorganism can get into the product.

xi. The degree of heat and the length of time of heating vary with the type of food and the kinds of microorganisms that are likely to occur in it. High-acid foods such as fruits and tomatoes can be processed or "canned" in boiling water, while low-acid vegetables and meats must be processed in a pressure canner at 121°C (15 psi pressure).

xii. Tin-coated steel cans are most commonly used followed by glass containers. Nowadays, containers made of aluminum and

Use of Chemical Preservatives

Chemical preservatives are food additives, which are specifically added to prevent the deterioration or decomposition of a food. Chemicals are used to inhibit the factors causing spoilage. These are also used to complement other food preservation techniques.

Preservation of foods by the chemicals is effected by interfering with the cell membrane of the microorganism, their enzyme activity and genetic mechanism; and by acting as antioxidants. In food preservation, the added chemical preservatives may be grouped into two classes.

•**Class I preservatives:**

The first one includes the use of sugar, salt, spices, acetic acid (vinegar) and alcohol, and is referred to as class I preservatives and is considered to be relatively safe to humans.

Class II preservatives:

The second group includes the use of benzoic acid, sulfur dioxide, nitrates and nitrites and a variety of neutralizers, firming agents and bleaching agents and referred to as class II preservatives and is considered to be relatively safe to humans, but within the permissible doses prescribed by the food regulatory bodies of the country because higher concentrations can be a health hazard.

Carbonation

Carbonation is the process by which carbon dioxide gas is dissolved in food under pressure. The [principle](#) behind this is that by eliminating oxygen, carbon dioxide inhibits bacterial growth. E.g. carbonated beverages (soft drinks), therefore, contain a natural preservative.

Irradiation

Food irradiation is low temperature sterilizing technique as in this case, [sterilization](#) can be effected at room temperature. Foods are exposed to high-energy rays called gamma rays or by fast-moving electrons, which kill [bacteria](#), fungi and insects. In some cases, irradiation delays fruit ripening. A major advantage of irradiation is that it can be done after the food is packaged and sealed. It has been used in pasteurizing or sterilizing perishable foods such as meat, fish and fruits and extending their storage lives for long periods. It is also used for sprouting inhibition in onions, potatoes etc. Cobalt-60 or Cesium-137 or electrons producing machines are the principal sources of ionizing radiations used for food irradiation.

Combination of Two or More of the Above methods or Hurdle Technology

Hurdle or barrier concept is based on synergistic action of preservatives and other treatments to preserve food. Hurdle in food is defined as the substance or the processing step or various preservation factors, inhibiting the growth of various microorganisms resulting in the death of microorganisms. Higher the hurdle, greater is the effect. The quantification of various factors in terms of pH, redox-potential, water activity, temperature, preservatives etc. gives the successful level of combination of hurdles, which lead to failure of growth and finally in death of microbes. Hurdle technology helps to give shelf stable food product, with superior quality and with fresh like characters.

Lesson 12: Preservation by Chemical Preservatives

Chemical preservation of perishable foods by various additives or preservatives is a significant part of the food preservation industry which is used in combination with other forms of preservation like [freezing](#), [canning](#), dehydration etc. Chemically preserved food products like squashes and crushes etc. can be kept for a fairly long time even after opening the seal of the bottle. It is however essential that the use of chemicals is properly controlled as their indiscriminate use is likely to be harmful. These should be added in very low quantities so that organoleptic and physico-chemical properties of the foods are not altered at all or only a little.

Preservation Principle

Food preservatives interfere with the mechanism of cell division, permeability of cell membrane and activity of enzymes and inhibit the spoilage factors. These work either as direct microbial poisons or by reducing the pH to a level of acidity that prevents the growth of microorganisms.

Benzoic Acid and Related Compounds

Definition of Food Preservative

Preservatives are the chemical agents which serve to retard, hinder or mask undesirable changes in food. More precisely, preservatives are substances when added to food to retard, inhibit or arrest the activity of microorganisms such as [fermentation](#), acidification and decomposition of food or of masking any of the evidence of putrefaction but it does not include salt, sugar, vinegar, glycerol, alcohol, spices, essential oils etc. According to Prevention of Food Adulteration (PFA) Act (1954) and Food Standards and Safety Act (FSSA) of 2006, a 'preservative' means a substance which when added to food, is capable of inhibiting, retarding or arresting the process of [fermentation](#), acidification or other decomposition of food.

Preservatives may be anti-microbial preservatives, which inhibit the growth of [bacteria](#) and fungi, or antioxidant such as oxygen absorbers, which inhibit the oxidation of food constituents. Common anti-microbial preservatives include calcium propionate, sodium nitrate, sodium nitrite and sulfites (sulfur dioxide, sodium bisulphite, potassium hydrogen sulphite, etc.) and ethylenediamine tetraacetic acid (EDTA). Antioxidants include butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT).

Sulphur dioxide (including sulphites) and benzoic acid (including benzoates) are among the [principle](#) preservatives used in the food processing industry.

Classes of preservatives

Under PFA (1954) and FSSA (2006), preservatives are classified into two classes Class I and Class II preservatives

Class I preservatives include mainly natural products which are used comparatively in higher concentrations than class II preservatives. There is no restriction to the addition of Class I preservatives to any food. For example- common salt, sugar, dextrose, spices, vinegar or acetic acid, honey, vegetable oils etc.

Class II preservatives are generally synthetic chemicals used in small quantities. Use of more than one class II preservatives is prohibited. For instance- benzoic acid and its salts, sulphur dioxide and the salts of sulphurous acid, nitrites and nitrates, sorbic acid and its salts, propionic acid and its salts, lactic acid and its salts, methyl or propyl parahydroxy benzoic acid, sodium diacetate are used.

The permitted usage levels of various chemical preservatives in different preserved food products are given in Table 1.

Table 1. Permitted usage levels of chemical preservatives in foods

Chemical preservative	Concentration (ppm)	Foods
Sorbic acid and its salts (calculated as sorbic acid)	50	Nectars, ready to serve beverages in bottles/pouches selling through dispenser
	100	Fruit juice concentrates with preservatives for conversion in juices, nectars for ready to serve beverages in bottles/ pouches selling through dispensers
	200	Fruit juices (tin , bottles or pouches)
	500	Jams, jellies, marmalades, preserve, crystallized glazed or candied fruits including candied peels fruit bars
Benzoic acid and its salts	120	Ready to serve beverages
	200	Jam , marmalade, preserve canned cherry and fruit jelly
	250	Pickles and chutneys made from fruits or vegetables
	600	Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets
	750	Tomato and other sauces; Tomato puree and paste
Sulphur dioxide	40	Jam , marmalade, preserve canned cherry and fruit jelly
	150	Crystallized glaze or cured fruit (including candied peel)
	350	Squashes, crushes fruit syrups, cordials, fruit juices and barley water or to be used after dilution; Syrups and sherbets; Fruit and fruit pulp
	2000	Dehydrated vegetables
Sodium and/ or Potassium nitrite expressed as Sodium nitrite	200	Pickled meat
Lactic acid	No limit	Fermented meat, dairy and vegetable products, sauces and dressings, drinks.
Citric acid	No limit	Fruit juices; jams; other sugar preserves
Acetic acid	No limit	Vegetable pickles; other vegetable sauces, chutney Source: FSSA (2006) and Garg et al. (2010)

Benzoic Acid and Related Compounds

Benzoic Acid and Related Compounds

Sodium benzoate was the first chemical preservative permitted in foods by the FDA, and it continues to be widely used in large number of foods. Benzoic acid and its related compounds possess antimicrobial activity and their antibacterial action increases in the presence of CO₂ and acid. For example- Bacillus subtilis cannot survive in benzoic acid solution in the presence of CO₂. As used in acidic foods, these act essentially as a mould and yeast inhibitor. In fact, benzoic acid is more effective against [yeasts](#) than against [moulds](#). It does not stop lactic acid and acetic acid [fermentation](#). Benzoates have greatest activity at low pH especially in food products with pH below 4.5. Optimum functionality occurs between 2.5 and 4.0 pH. Benzoic acid is mostly used in coloured products of tomato,phalsa, jamun, pomegranate, strawberry, coloured grapes etc. as in the long run, it may darken the product.

Sodium benzoate, sodium salt of benzoic acid, is very effective as it is nearly 180 times more soluble in water than benzoic acid. It produces benzoic acid when dissolved in water. It should be used at low levels to avoid possible off-flavours in some products. The maximum level allowable by PFA act is 0.075 per cent. It is used in fruit products, jams, relishes, beverages etc. and is effective against [yeasts](#), some [bacteria](#) (food borne pathogens but not spoilage [bacteria](#)) and some [moulds](#).

Sorbic acid and related compounds

Sorbic acid and related compounds have antimicrobial properties. They are available as sorbic acid, potassium sorbate, sodium sorbate or calcium sorbate. Salts of sorbic acid are used in many cases as they are highly soluble in water and produce sorbic acid when dissolved in water. The potassium salt of sorbic acid i.e. potassium sorbate is much more soluble in water than the acid. It does not impart any noticeable flavour at normal usage concentrations. Maximum level allowable by PFA act is 0.3 per cent. It is effective up to pH 6.5 but effectiveness increases as the pH decreases. It has about 74 per cent of the antimicrobial activity of the sorbic acid, thus it is required in higher concentrations than pure sorbic acid. It is effective against [yeasts](#), [moulds](#), and select [bacteria](#), and is widely used at 0.025 to 0.10 per cent levels in cheese, beverages, fermented and acidified vegetables, smoked and salted fish. In wine processing, sorbates are used to prevent refermentation.

Propionic Acid and Related Compounds

Propionic Acid and Related Compounds

Propionic acid inhibits mould and rope [bacteria](#) growth but negligible effect on yeast. Propionic acid and its salts, sodium and calcium propionates, are approved by USFDA as GRAS (Generally Recognized As Safe) substances for food use and also by PFA act in India. Propionates are effective up to maximum limit of 5.5 pH. They are used in preserving cheese, non-alcoholic beverages, jams and jellies. Typical usage level of propionic acid and propionates is 0.2 per cent.

Parabens

The parabens are alkyl esters of para-hydroxy benzoic acid. The two most common esters are methyl and propyl parabens approved by USFDA as GRAS. PFA act has mentioned it among the class II preservatives. The maximum concentration allowed is 0.1 per cent. They are most active against [yeasts](#) and [moulds](#) (0.5-0.1 per cent) but ineffective against [bacteria](#), especially gram negative [bacteria](#).

Solubility of parabens increases with increase in temperature of water. Methyl paraben is more soluble in water but less effective against [moulds](#) than propyl paraben. Therefore, a mixture of methyl paraben (2 to 3 parts) with propyl paraben (1 part) is normally used to negate the difference in their solubility.

Parabens are effective at higher pH values from 3 to 8 and also stable at low and high temperatures, even up to steam [sterilization](#). But they are not as widely used due to high cost and objectionable flavour. They are used in beverages, jams, jellies, preserves, smoked fish and pickles.

Lactic acid

Lactic acid is formed by microbial [fermentation](#) of sugars in preserved food products such as sauerkraut and pickles. The acid produced decreases the pH to levels unfavourable for growth of spoilage organisms such as putrefactive anaerobes and butyric-acid-producing [bacteria](#). It does not control [yeasts](#) and mould growth, which can grow at such pH levels. Inclusion of other preservatives such as sorbate and benzoate may be used in that case.

Acetic acid

It is also known as vinegar. Acetic acid is a general preservative inhibiting many species of [bacteria](#), [yeasts](#) and to a lesser extent [moulds](#). It is also a product of the lactic-acid [fermentation](#). It is more effective in preservative action than lactic acid at same pH levels. It is mainly used in products such as pickles, sauces and ketchup.

Sulphur dioxide and sulphites

Sulphur dioxide and its derivatives have been widely used in foods as a food preservative. It serves both as an antioxidant and reducing agent and prevents enzymatic and non-enzymatic reactions, leading to microbial stability. The common used forms are sulphur dioxide gas and sodium, potassium and calcium salts of sulphite, bisulphite or metabisulphite, which are powders. Various sulphite forms dissolve in water and yield 50 to 68 per cent sulphur dioxide gas. It has bactericidal and bacteriostatic properties and is more effective against [bacteria](#) especially gram negative [bacteria](#) than [moulds](#) and [yeasts](#).

Sulphur dioxide gas (SO₂) is one of the oldest known fumigant and a wine preservative. The gaseous form is produced either by burning sulphur or by its release from the compressed liquefied form. It is a colourless, suffocating, pungent-smelling, non-flammable gas and highly soluble in cold water.

Sulphites are effective in producing more SO₂ ions at pH values less than 4.0. Metabisulphite are more stable to oxidation than bisulphites and the latter show greater stability than sulphites.

Sulphites inhibit microbial growth by reacting with the energy rich compound like adenosine triphosphate; inhibiting some metabolic pathways; and blocking cellular transport systems. Sulphur dioxide also inhibits browning, both enzymatic and nonenzymatic, reactions in fruits and prevents darkening of colour and alterations of flavour. Therefore, sulphites are used to prevent or reduce discolouration of light-coloured fruits and vegetables, such as dried apples and dehydrated potatoes. These are added to sun-dried tomatoes, dried apricots, dried potatoes and lemon juice. These are also commonly used to lengthen the life of fruit juices.

They are also used in wine-making because they inhibit only bacterial growth but do not interfere with the desired development of yeast. Potassium metabisulphite (KMS) is generally used in non-coloured products whereas in coloured products containing anthocyanin pigment, sodium benzoate is used to prevent discolouration.

Nitrites have been used in meat curing for many centuries. It is used along with a mixture of salt, sugar, spices, and ascorbate for curing meats. Nitrite contributes to the development of the characteristic colour, flavour and texture improvement in addition to preservative effects. Sodium nitrite is quite soluble in water and is more effective below neutral pH (below 7.0). Along with salt, nitrite exhibits stronger antimicrobial action.

Nitrates break down in the body to nitrites and this stops the growth of [bacteria](#), especially *Clostridium botulinum*, the [bacteria](#) that cause botulism poisoning. This is the reason nitrites and nitrates are used mainly among the packaged meats. Nitrites also stabilize the red colour in cured meat and stop it from turning grey. Nitrates get readily converted into nitrites, which then react with the protein myoglobin to form nitric oxide myoglobin. During cooking, this is converted to nitrosohemochrome, a stable pink pigment, which impart a pink, fresh hue to cured meat. This chemical stabilizes the red colour of the meat and gives an appearance of fresh meat. That is why nitrites are a preferred preservative of meat processors even though its excess use is restricted in many countries.

Nitrite salts should be used with precaution because they can react with certain amines in food at acidic pH to produce nitrosamines, which are known to cause cancer by giving rise to compounds like nitrodimethyl-amine. Addition of sodium ascorbate inhibits nitrosamine formation and reduces the problem of nitrosamines. Nitrites and nitrates are permitted as preservatives in cured meat and meat products including poultry at levels below 200 ppm by USFDA and FSSAI in India.

Antibiotics

Antibiotics are antimicrobial substances produced by microorganisms have been allowed for food use only in recent years. But they are not widely used in food preservation due to the risk of ill effects on consumer and possibility of appearance of resistant strains. However, nisin and have been permitted in some foods.

Nisin

Nisin is a polypeptide produced by *Streptococcus lactis* (now called *Lactococcus lactis*). Its solubility depends on the pH of the medium and it is more soluble in acidic pH. Its antimicrobial action increases as the pH decreases. Nisin has a narrow spectrum affecting only gram-positive [bacteria](#), including lactic acid [bacteria](#), streptococci, bacilli, and clostridia. It does not inhibit gram-negative [bacteria](#), [yeasts](#) or [moulds](#). Nisin has been permitted in processed cheese up to 12.5 ppm under FSSAI.

Natamycin

Natamycin is produced by the bacterium *Streptomyces natalensis*. The compound has a large lactone ring which is substituted

Ethylenediamine Tetra Acetic Acid (EDTA)

EDTA is a metal-chelating agent which removes the metal cofactors that many enzymes need, thus preventing the food spoilage. But, it is not mentioned under FSSAI as preservative.

- **Antioxidant preservatives**
- Antioxidant preservatives prevent foods from becoming rancid, browning, or developing black spots by suppressing the reaction that occurs when foods combine with oxygen in the presence of light, heat, and some metals.
- Antioxidants also minimize the damage to some essential amino acids and loss of some vitamins.
- Antioxidant preservatives, such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), tert-butylhydroquinone (TBHQ), and propyl gallate (PG), stop the chemical breakdown of food that happens in the presence of oxygen by inhibiting the free radicals that help initiate and propagate these reactions.