

## FOOD SPOILAGE, STORAGE, AND PRESERVATION

### Abstract

Food storage is not only linked with safety and quality but also plays a significant role in the effective balancing of family income and maintaining the utilization of available resources in the country. The process of food storage should immediately start with the harvesting, manufacturing, and slaughtering of the animal or plants because the process of chemical composition begins soon after it. These changes worsen the condition of food and may cause it to deviate from its appearance, taste, and composition that termed spoilage. As we all know, food is a basic necessity of life and is irreplaceable for the healthy existence of mankind. Utmost of our food is comprised of plant and animal products, which are generally seasonal and spoil quickly. The harvested, caught, slaughtered, or manufactured products from those progressively goes deteriorates or spoiled until and unless it is preserved within the time. This deterioration is either caused by the production of toxic substances by microbes or the loss of nutritional value. The main aim of food storage is to guarantee safe and high-quality food. The proper storage of food increases the shelf life of the food, which basically depends on the type, packaging, and storage conditions such as humidity and temperature. The main aim of the chapter is to make aware of the term food spoilage, and food preservation, and to understand food based on perishability, and the different methods of food preservation (conventional and modern methods). The book chapter also included the recent advances used in food preservation elaborately.

**Keywords:** Food spoilage; storage; preservation; HACCP; microbes

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## I. INTRODUCTION

As we all know, food is a basic necessity of life and is irreplaceable for the healthy existence of mankind. Utmost of our food is comprised of plant and animal products, which are generally seasonal and spoil quickly. The harvested, caught, slaughtered, or manufactured products from those progressively goes deteriorates or spoiled until and unless it is preserved within the time. This deterioration is either caused by the production of toxic substances by microbes or the loss of nutritional value (FDNT, 2021). The main aim of food storage is to guarantee safe and high-quality food. The proper storage of food increases the shelf life of the food, which basically depends on the type, packaging, and storage conditions such as humidity and temperature (McCurdy et al., 2009).

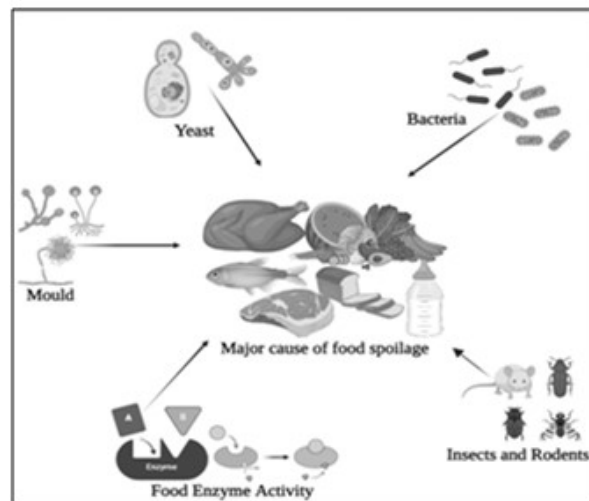
Food storage is not only linked with safety and quality but also plays a significant role in the effective balancing of family income and maintaining the utilization of available resources in the country. The process of food storage should immediately start with the harvesting, manufacturing, and slaughtering of the animal or plants because the process of chemical composition begins soon after it. These changes worsen the condition of food and may cause it to deviate from its appearance, taste, and composition that termed spoilage (IGNOU, 2017).

**1. Food Spoilage:** The foods in their natural form resist infection and microbial attack by the healthy cells present inside them. So, any adverse changes in food quality such as taste, texture, appearance, aroma, and flavour along with nutritional value, shelf-life, and safety may cause spoilage of foods. The deterioration of foods depends on the type of food and their rapid or slow deterioration, and if not controlled might be dangerous for health (FDNT, 2012; IGNOU, 2017). There is a natural fact that the spoiling of perishable foods deteriorates rapidly compared to non-perishable foods, depending on several factors, which will describe briefly below. Generally, food spoilage begins from poor sanitation, enzymatic, and chemical reactions, uncontrolled temperature, microbial growth, and physical handling during food processing and lasts till it's consumed. So, spoiled foods are deprived of their good and effective quality. As we learned, spoiled food undergoes alteration of physiological, chemical, and biological changes, which makes food hazardous and inedible to eat.

- **Major Cause of Food Spoilage:** In this section, we will learn the various cause of food spoilage. The major cause of food spoilage is known microbial contact, enzymatic reaction, and interaction of insects and rodents. Let's discuss each attribute elaborately.
- **Microorganism:** Microorganisms generally exist everywhere-soil, air, water, over human and cattle skin, feathers of poultry, and in the intestinal cavity and hair, nails and so. The microbes exist on the skin, and peel of vegetables and fruits, also on non-living things such as experimental equipment, and utensils. Generally, the microbes are not found within the fruit or flesh, but as it presents over the skin so they invade the flesh of plants and animals through the breaking of the skin. The microbes such as bacteria, yeast, moulds, protozoa, algae, and others. Among which the food spoilage agents are bacteria, moulds, and yeast, which may cause a variety of changes

(chemical and physical changes) within the food and cause it to spoil by its toxins (Cockell, 2021).

- **Bacteria:** These microbes are of various shapes (curved, slender, long, and corkscrew) viewed under a microscope. They look simply but they bring various complex changes in foods and cause spoilage of meat, fruits, dairy, fish, and poultry products. Bacteria are alkaline or acidic in nature. Some bacteria can be destroyed upon cooking, heating, and low-temperature treatments (Zhu et al., 2022).
- **Yeast:** Yeast represents another class of microorganisms. It helps to ferment the food and is used in preparing various food products such as bread, idli, dhokla, etc. Whenever the process of fermentation goes unlimited causes spoilage. The process of fermentation can harm the quality of foods that depends on the amount of alcohol produced during the process. A greater amount of alcohol production leads to greater spoilage of foods. In the case of fruit, the cooked one gets fermented easily due to the content of sugar present in it. We can see in fruit juice when kept for long days produces small tiny bubbles over it this is nothing but fermentation of the fruit juice that indicates excess fermentation or spoilage of juice (Maicas, 2020).



**Figure1:** Cause of the food spoilage

- **Moulds:** We can say moulds are tiny plants. They can grow easily to all kinds of foods in damp, warm, and dark places. They look terribly horrible when grow on foods, such as grey fuzzy growth on cheese and black hairy growth on bread. The growth of moulds over the foods can change the appearance, taste, and texture of foods, so avoiding such foods can be safe for health (Filtenborg et al., 1996).
- **Food Enzymes:** The term food enzyme is not new to us. The enzymes play an important role in the process of digestion and also in the various process of respiration, germination, and so on. The activity of enzymes remains as it is even after the harvested plants or slaughtered animals. The process needed to be continued for the ripening of fruits to a certain degree. However, the ripening of the fruits beyond

certain points causes the deterioration of the food product and lowers the quality. We have already seen that the over ripped banana and papayas can develop deteriorative changes in taste and texture (in't Veld. 1996).

- **Insects and Rodents:** Most of the wasting of foods especially grains destructed by insects and rodents. They can damage the foods both in the field and in storage areas by worms, weevils, moths, bugs, rats, and by others. They damage the foods and cause to expose them to bacteria, moulds, and yeast infections. A small invasion done by the insects causes the total decaying of the foods to microbial infection. The same issues are seen in the case of rodents. Rodents not only consume a much quantity of foods but also filth with which they contaminate the foods. Their urine and droppings harbour several kinds of disease-producing bacteria, which infect human health (DeMattia et al., 2004).

## II. THE FACTORS RESPONSIBLE FOR FOOD SPOILAGE

As we have learned the cause of food spoilage, now we will discuss the various factors responsible for food spoilage. Some of the factors like temperature, moisture, dryness, air and oxygen, light, and duration are also responsible for food spoilage (Hamad, 2012) which will discuss in brief below.

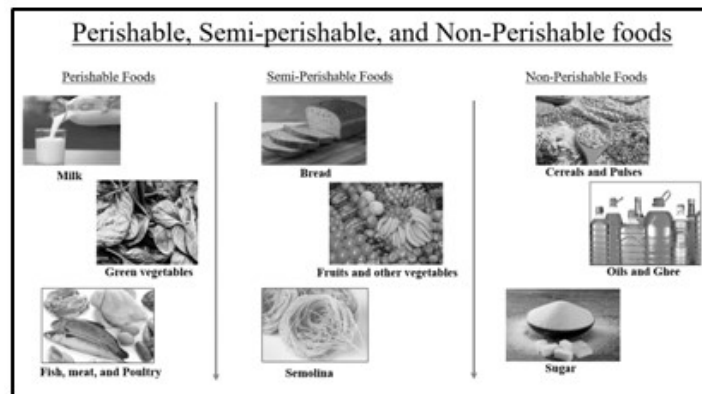
1. **Temperature:** Temperature is one of the responsible factors for food spoilage. As each microbe has an optimum temperature as they grow i.e., at that temperature they grow best and multiply rapidly (Sevindik & Uysal, 2021). Similarly, the enzymes have their optimum temperature for their activity. So, we can say that variation in the temperature can have an effect on microbial growth and enzyme action. Freezing and chilling are generally used to store foods at low temperatures. Excess heat and cold cause food deterioration by denaturing the protein content and vitamins of the foods. The excessive cold and freezing treatment causes the breakdown of food cells, and thawing allows microbes to get spoil the foods.
2. **Moisture and Dryness:** Excessive moisture and dryness also play an important role in food spoilage and food storage. Some foods are at their best state when they are moist and some are when dry, alterations may cause deterioration. Moisture or excess water activity and enzyme action are favourable for microbial growth. The moisture present in the foods promotes the bacterial and mould growth (FDNT, 2012; IGNOU, 2017).
3. **Oxygen and air:** The attractive color of foods is due to the presence of photochemical that acts as an antioxidant agent and provides the functional activity of foods. These foods also contain vitamins C, A, and flavour but get destroyed when exposed to air or oxygen. These attributes also provide a favourable environment for the growth of moulds. Food exposure to the air may bring dryness that may cause the deterioration of foods (FDNT, 2012; IGNOU, 2017).
4. **Light and Time:** Foods containing vitamins, minerals, or essential light-sensitive components that get destroyed when they come in contact with light. So, such foods should be protected from light by keeping them away from light, in dark-colored bottles or glazed pottery. As we know the foods have their peak quality and last for certain

periods of time. Such as harvested, slaughtered, or manufactured food products. Some of the foods last for 1 day (milk), 2-3 or a week (fruits and vegetables), and more than a week (cereals, pulses, and dried foods). It's also true that some foods may improve their quality upon standing for longer times such as cheese, wines, and pickles (FDNT, 2012; IGNOU, 2017).

### III. CLASSIFICATION OF FOODS ON THE PERISHABILITY

Our purchasing habits of the food are that when we go to the market to buy food, we bring lots of food that can spoil within a week or days. Such as milk can spoil within a day, fruits and vegetable take 2-3 days and some of them like rice, pulses, and dry fruits or purchased food takes more than a month or a year. But why these things are happening? To understand these things, Let's discuss the terms perishable, semi-perishable, and non-perishable (FDNT, 2012; IGNOU, 2017).

- 1. Perishable:** Perishable foods are categories those foods that spoil easily unless special methods adopt to prevent such spoilage. All the milk, and milk products, eggs, poultry, fish, meats, fruits, and vegetables come in this category. The spoiling of these foods depends on the temperature, moisture, and dryness of the environment, in cold it takes some time to spoil whereas in hot it spoils fast (FDNT, 2012; IGNOU, 2017).
- 2. Semi-Perishable:** These foods can survive for a couple of weeks or for months without any perceptible signs of spoilage. Here also the humidity and temperature of the environments play a big difference. Cereals and pulses products such as semolina, vermicelli, bread, cake, Bengal gram flour, refined wheat flour, onion, potato, fats, and oils can be stored for a month or for a longer duration. Whereas in cold climates countries, these foods are considered as no-perishable foods, and humid or hot environments cause the opposite (FDNT, 2012; IGNOU, 2017).
- 3. Non-Perishable:** Non-perishable foods are those foods that can be stored for a longer duration of time even when they are handled or stored carelessly. In this type of food, the proper measures are only adapted to avoid the development of insects or moulds, especially in monsoon seasons. The foods included in this category are cereals, pulses, ghee, pickle, and sugars (FDNT, 2012; IGNOU, 2017).



**Figure 2:** Classification of foods based on perishability

- 4. Food Storage:** Storing food is the right way to ensure an adequate food supply not only at the household but also at the national level. At the point of harvesting, the loss of the grains extends from 5-10 % of the total production of all developed countries, 50 or more of the developing countries, and is a massive waste of all valuable food sources. In our countries, the loss of grains is 10% at the farmer level, and lose 17 million tonnes of such grains just due to improper or infacility of storage. This section will discuss the importance of food storage and different methods of food storage (IGNOU, 2017).

Food storage indicates different ways to store foods so that the foods can keep for a longer period without any physical, chemical, or other changes. So, we can say to increase the shelf life of food. A shelf life of food means the length of time a food remains safe and fit for human consumption (NTM).

#### IV. THE IMPORTANT POINT, IS WHY THE FOOD STORE?

- To keep the food in a good and fresh condition for as long as possible.
- To protect it from microbial, chemicals, insects and rodents, or others to avoid food contamination and spoilage.
- Reduce the loss of food lost while after harvesting, and slaughtering.
- Reduce the cost of the food that damages before the shelf life.
- We can buy seasonal food products in bulk, which will save money, without rushing, which can reduce stress.
- Some traditional methods of storage such as fermented food products (pickles, fermented foods) can add beneficial microbes to the diet that can improve the health benefits.

#### V. SPOILAGE OF DIFFERENT FOOD GROUPS

- 1. Spoilage of Meats:** Meat is nothing but a bulk of muscular tissues and an edible part of the carcasses of animals after slaughtering. After slaughtering, the tissue's ability to fight against microbes is lost, so it is the nutrient storehouse with high water activity i.e., 0.99, and suitable for microbial growth. Bacteria and other organisms can grow very easily on and over it. As we have already learned in the above section that after slaughtering the body's mechanism is withdrawn and undergoes biochemical changes. So, the enzymes present in the meat acts on the muscle protein which increases the nitrogen content for suitable growth of microorganism. After slaughtering the meat gets stiff and rigid, which is known as rigor mortis (stiffening of muscular tissues)? The continuous increase of enzyme action causes autolysis of muscular tissues which makes meat sour (Dave & Ghaly, 2011).

- **Factors Responsible for Meat Spoilage**

- **Initial Microbes:** The microbial loads regulate the storing time under good preservation conditions. The hygiene condition is an important and crucial part to reduce the proliferation of microorganisms (Pellissery et al., 2020).

**Table 1: Microbes responsible for meat spoilage**

<b>Bacteria</b>	<b>Moulds</b>
<b>Bacillus</b>	<i>Cladosporiumherbarum</i> (Black spot over the meat)
<b>Pseudomonas</b>	<i>Sporotrichumcarnis</i> (white spot over the meat)
<b>Micrococcus</b>	<i>Penicilliumexpansum, P.asperulum</i> (Green spot over the meat)
<b>Clostridium spp.</b>	<i>ThamnidiumchaetocladioidesTelegans, Mucormucedo, M.insitanicus</i> (whiskers spot over the meat)

Table adapted from IGNOU (2017a)

- **pH:** The pH of slaughter meat increases the acidity and drops the pH from 7 to 5.6, as the stored glycogen in muscle is used by the muscular cells slowly and produces lactic acids. But if the animal is slaughtered abnormally due to stress or excitement the stored glycogen is used by the muscle rapidly and thus the reduction in pH not occurs and remains at 7. The condition causes the growth of microbes and spoilage of meats (Koutsoumanis et al., 2006).
- **O-R Potential:** After slaughtering, the stored oxygen within the muscle gets reduced and brings oxidation-reduction potential. This condition is favorable for aerobic bacteria, yeast, and moulds growth. The internal part where the oxygen is not present causes the growth of anaerobic bacteria (Dave, & Ghaly, 2011).
- **Temperature:** The carcass meat is held at a temperature above 20 °C and spoiled by anaerobic bacteria (Dave, & Ghaly, 2011).

**2. Spoilage of Poultry and Poultry Products:** Poultry meat is nothing but the muscle tissue or protein of duck, chicken, turkey, etc. The spoilage of poultry occurs in the same way as the meat muscle. If proper handling is not taken, then bacterial growth starts, once takes place, off-odour generally occurs and follows slime formation. Above 10 °C, the bacterial and other microorganism growth starts. Once the bacteria invade, causes a common form of spoilage known as rotting. There are different types of rots encountered (Cervený et al., 2009).

**Table 2: Microbes responsible for different kinds of Rots in poultry and poultry products**

<b>Different colour Rots</b>	<b>Organism responsible</b>
<b>Black</b>	Proteus, Pseudomonas, and Aeromonas
<b>Red</b>	Serratia marcescens
<b>Pink</b>	Pseudomonas
<b>Green</b>	Pseudomonas fluorescence
<b>Colourless</b>	Acinetobactor, Pseudomonas and Alcaligenes

Table adapted from IGNOU (2017a)

**3. Spoilage of Fish and Marine foods:** Fish and other seafood places second position only to meat and poultry as animal food worldwide. India is known as a fish-producing country due to its vast sea coast and several inland water sources. Fish is a regular diet in the population residing in the coastal district and is even consumed in a dried and salted way (IGNOU (2017a)).

- **Factors Responsible for Fish and Marine Food Spoilage**

- **Shape and size:** Big and fatty fish are more susceptible to oxidation due to unsaturated fats and oils present in them. Whereas the thin fish rapidly spoil due to rigor mortis.
- **Initial Microbes:** The skin, gills, and intestine contain bacteria and other organism, and after catching them if not handled properly causes microbial load and rapidly spoil.
- **Temperature, Water, and Air:** Fish from warm seas are contaminated with mesophil strains while fish from cold region contains psychotrophs.
- **Improper Handling:** Caught fish if stored in unpotable water, or contaminated cause microbial contamination. Cross-contamination happens from earlier catches, boats, baskets, and nets and the sanitary condition.
- **Chemical Changes:** Fish containing high levels of PUFA (polyunsaturated fatty acids) are more pronounced for oxidative rancidity than other fish. The trimethylamine oxide is reduced to trimethyl amine due to the enzymatic action and bacterial contamination, which causes spoilage of fish, and as an indicator used.

**Table 3: Fish and Marine Fish Contamination by Microorganisms**

Type of sea foods	Microorganisms
Fresh fish	<i>Pseudomon</i> , <i>Acinetobacter</i> <i>Moraxella</i> <i>Pseudomonas</i>
Salted fish	<i>Halobacterium</i>
Shrimps	<i>Pseudomonas</i>
Oysters	<i>Rhodotorula</i>

Table adapted from IGNOU (2017a)

**4. Spoilage of Vegetables and Fruits:** To be healthy, we need to take fruits and vegetables every day in an adequate amount or as recommended by RDA (Recommended dietary allowance). But if the harvested fruits or vegetables are not stored or handed properly then they will get spoil. The spoiling happens mostly during post-harvesting treatments such as packaging, transport, and storage. Due to the enzymatic activation both fruits and vegetables undergo ripening process but uncontrolled enzymatic activation causes over-ripening or browning, which leads to spoilage of foods IGNOU (2017a).



- **pH:** The pH of the most fruits and vegetables lies from 5 to 7, and most fungi and bacteria grow suitably at that pH.
- **Enzymes:** Most of the bacteria and fungi secrete pectolytic enzyme, causes breakdown of the cellular wall and get easily invade within the cell and causes rot.
- **Initial Microbes:** The spoiling done by bacteria (*Erwinia* Spp. *Erwinia carotovora* and *Pseudomonas* Spp.), fungi and moulds. Most important moulds responsible for the spoilage of vegetables and fruits are *Penicillium* and *Rhizopus*.

**Table 4: Microbes responsible for different kind of rot production in vegetables and fruits**

Genus	Spoilage Effects
<i>Penicillium</i>	Bluerot
<i>Rhizopus</i>	Softrot
<i>Sclerotinia</i>	Watery softrot in vegetables, brown rot in fruits
<i>Geotrichum</i>	Sourrot
<i>Alternaria</i>	Blackrot

Table adapted from IGNOU (2017a)

5. **Cereals and Cereals Products:** Most of the energy we get from the cereals and cereals products. Not only in India but also in other parts of the country, wheat, and rice are the staple food. For the preparation of snacks, confectionaries, and cereals are commonly and majorly used ingredients. Such as chapati, bread, bakery and pastries, cereals and cereal products generally used. As the cereals have low water activity content so considered semi-perishable or non-perishable products. But if it is not stored in a favorable place (such as less humidity or low moisture place) then gets spoiled. Moulds, yeast, and bacteria are the causative agents for the spoilage of cereals and cereals products. The wheat, maize, and sorghum infected by mould such as *Aspergillus* and *Fusarium staphylococcus aureus* commonly found in pastries due to the addition of milk products IGNOU (2017a).

**Table 5: Microbes responsible for different kinds of spots in cereals product**

Bread	
Organism	Spots
<i>Rhizopus nigricans</i>	Black Spot
<i>Penicillium expansum</i> and <i>Aspergillus niger</i>	Green Spot
<i>Manilia sitophila</i>	Pink Spot
<i>Serratia marcescens</i>	Red spot

Table adapted from IGNOU (2017a)

## 6. Spoilage of Milk and Milk Products

- **Butter:** Butter contains high amounts of fat. Due to high content of fat, it undergoes rancidity and microbial spoilage. The microbes associated with butter spoilage are Psychrotrophic bacteria. The Putrid, fruity flavour in butter is due to Psychrotrophic bacteria spoilage. The fruity odour in the butter is also caused due to spoilage by *Fluorescens* and *Pseudomonas fragi*. Both putrid and taint flavour are caused by *Altermonas putrefaciens* and *Pseudomonas putrefaciens* IGNOU (2017a).
- **Cheese:** Cheese mostly spoiled by growth of moulds. The genera of mould are *Penicillium*, *Cladosporium*, *Candida* and *Mucor* over the surface. The slimy nature caused due to *Pseudomonas* and gas formation due to Coliform bacteria. The pink colouration spoilage caused due to *Rhodotorula*, yeast.
- **Condensed, dried milk powder and frozen milk dessert:** Condensed milk spoilage caused due to Osmophilic yeast and *Torulopsis* spp. Whereas, *Micrococcus flavus* and *Bacillus subtilis* can spoil the dried milk also. The *Salmonella* spp. generally responsible for frozen milk product spoilage.

## VI. METHOD OF FOOD STORAGE

1. **Storage of Perishable Foods:** The low-temperature treatment helps to keep fresh perishable foods because it slows down enzyme activity and microbial growth. A domestic refrigerator is generally used to store perishable foods. The temperature of the domestic refrigerator used varies between -6 to 10 °C.
  - **Storage of Meat, Fish, and Poultry:** These food products can be stored in a deep freezer at -6 °C. They should not keep for a longer duration (more than 2 hours) at room temperature. If the refrigerator facility is not available at home, then quick cooking is safe to avoid deterioration. The spoiling of organ meat such as the brain, liver, and kidney is faster than the other portion of meat. Storing it with the addition of salt reduces microbial growth.
  - **Storage of Eggs:** The eggs should not store more than 2-3 days at room temperature. Can be stored in the refrigerator for longer use.
  - **Storage of Milk and Milk Products:** The boiling of milk destroys the microbes and the enzyme activity, so immediate boiling of purchased milk can be stored for 5-6 hours at room temperature. In the refrigerator, the shelf life of the cooked milk can last for 3-5 days.
  - **Fruits and Vegetables:** The spoilage depends upon the types of vegetables. Green leafy vegetables deteriorate faster than other vegetables, but storing them in the refrigerator increases the shelf life of the fruits and vegetables. The use of plastic covering or storing within the plastic bag reduces the excessive dryness of the fruits and vegetables which promotes longer storage IGNOU (2017c).

## 2. Storage of Semi-Perishable Foods

- **Cereal Products:** The product formed from cereals such as semolina, vermicelli, and Dalia can produce the off-odor or be damaged by insects and rodents very easily. They all should be kept after sieving, cleaning in a tightly closed container after exposing them to the sun for a few seconds.
- **Roots and Tubers:** Potato and onions should be stored in a dry, cool, and airy place to prevent them from growing shoots and moulds. The first come first use (the product first buy should have to use first) principle should be allowed.
- **Nuts:** It is infested by insects very easily and due to fat content, it becomes rancid also. Should have to store in a plastic mesh basket IGNOU (2017c).

## 3. Storage of Non-perishable Foods

- Cereals, pulses, salt, sugar, and some spices can be stored for a year. But still, there are some precautions we need to adopt.
- First, we need to clean them to remove the gravel, foreign matter, and husk, if possible, wash them with clean potable water and thoroughly dry them in the sun.
- Should have to store in a clean and air-tight container to avoid microbial, insect, and air contact.
- Should have to store in the storage cupboard IGNOU (2017c)s.

## VII. FOOD PRESERVATION

Food preservation is the process to treat and handle a portion of food in order to avoid spoilage by food-borne disease-causing microbes, autooxidation of fats results in rancidity and keeping the nutrient value, texture, flavour, and other properties of foods as it is.

In other words, it can also define as the arts of science that involve the process of preventing decaying foods and making them available for future use. This gives suitable physical and chemical treatment to the perishable, semi permeable, and non-perishable food to prevent their wastage or spoilage to store all the nutrients, quality, and quantity of the foods. The process of food preservation starts with a complete understanding and analysis of the whole food chain such as the growing of crops, harvesting (pre & post) processing, packaging and transportation, and delivery to consumers. So, we can say that food preservation lies at the heart of food science and technology. First, we need to understand the characteristics of the food that we have to preserve because one treatment is applicable for one product and may differ for the other product. The process of preservation is also applied to the particular properties or characteristics of the product. For example, the process of crust formation is desirable for the long bowl life in the case of cereals ingredients whether quick rehydration is needed for the instant soup ingredients. In another case, the customer expects apple juice should be clear and transparent whereas orange juice should be cloudy (Rahman, 2007).

## 1. Need for Food Preservation

- By using a simple method of food preservation, inadequate and improper management in agriculture production can be overcome.
- For increasing the availability of short-growing seasonal foods.
- Utilizing surplus crops and preventing wastage.
- The shelf life of the stored raw material could be increased,
- The preservation method of the value-added food products can give good quality food in terms of functional, nutritional, sensory properties, and convenient way.
- The eating of preserved food should be pleasurable to the consumer not boring. In this way, consumers get varieties of foods with different tastes and flavours.
- Safety is the primary concern followed by other qualities. The food quality varies on the type of food, composition in the food, types of packaging, and storage condition. So, by the preservation method, the quality loss can be minimized at any stage of food harvesting, processing, production, distribution, and storage.
- To ensure the supply of protective food in the home, hostel, and other places.

2. **Principle of Food Preservation:** During the process of food preservation, the following principle is needed, which is described by the picture illustration.

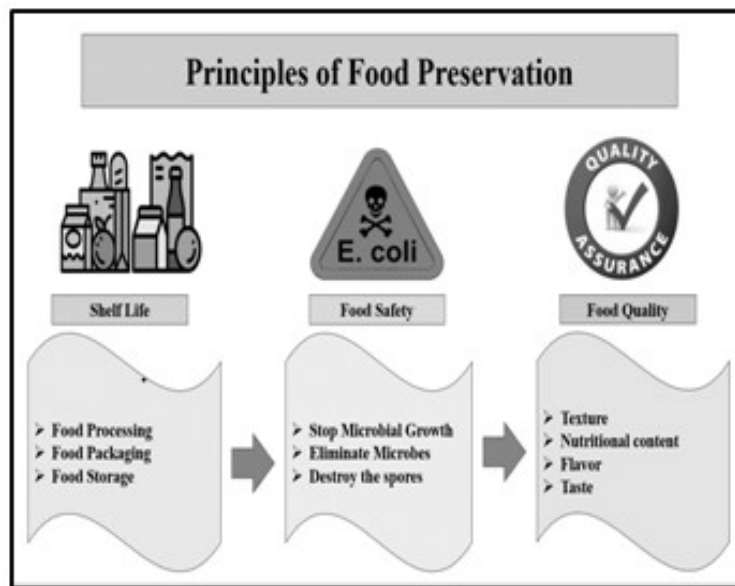
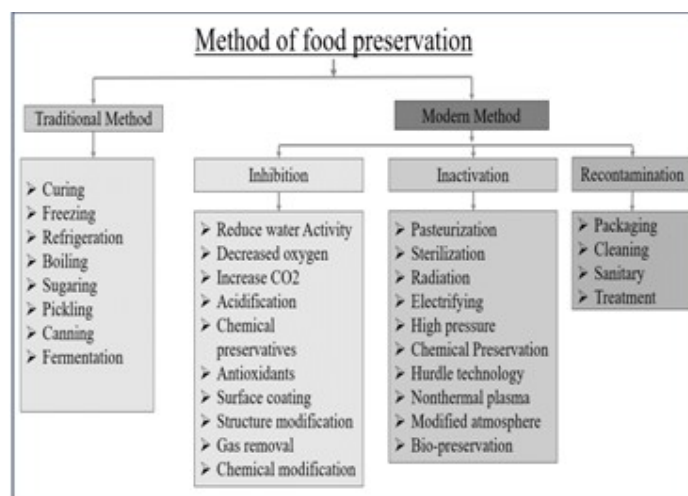


Figure3: Principles involve in food preservation

## VIII. METHODS OF FOOD PRESERVATION



**Figure 4:** Different methods of food preservation (Adapted from Rahman, 2007; Prokopov & Tanchev, 2007)

## IX. TRADITIONAL METHODS OF FOOD PRESERVATION

1. **Curing:** This method of preservation is used for fish, meat, and vegetable. In this, the moisture content of food is reduced by the process of osmosis. As we learned in the above section that the greater the moisture content in the food greater the risk for microbial contamination. The process is conducted by adding salt, sugar, nitrates, and nitrites in combination to reduce the hydration of the foods. This process also enhances the flavour of the foods. Higher salt or sugar content also shrinks the microbial cell and thus kills the microbes. It also stops auto oxidation and thus reduces the chance of rancidity (Kumar, 2019).
2. **Freezing:** In this method of food preservation, the food stored at a temperature lies from  $-10$  to  $-80$   $^{\circ}\text{C}$ , which is the common method adopted in cold & ice climate regions. Under this condition, the microbes generally do not survive, and if exist then are not multiplied. Because the enzyme activity at that temperature not happens (Kumar, 2019).
3. **Refrigeration:** It is an artificial process to bring the temperature below room temperature either mechanically or electrically. Processed and perishable foods were traditionally preserved by storing in a refrigerator. The temperature in this method of preservation lies from  $4$  to  $10$   $^{\circ}\text{C}$  (Kumar, 2019).
4. **Boiling:** Traditionally this method was adapted to kill the microbes present in or over the food. The raw foods are generally boiled at a temperature of  $100$   $^{\circ}\text{C}$  or above for a few seconds or minutes so that the microbes present on the surface or within the food completely destroy to avoid food spoilage from microbial contact (Kumar, 2019).
5. **Sugaring:** The principle behind this type of preservation is to make the foodstuff hypertonic. In the hypertonic condition, the microbes cannot survive or grow, because the hypertonic solution draws the water content from the microbes and make them dehydrated. The common hypertonic solute used for this type of preservation is sugar and

honey. It also enhances the taste of the foods. Jam and jellies are examples of this type of preservation (Kumar, 2019).

6. **Pickling:** In this method of preserving the foodstuff (vegetables, fruits, fish, and meats) emerges in vinegar, vegetable oil, salt, or sugar to bring the anaerobic fermentation by which the lifespan of included foodstuff can be increased along with the texture, flavour, and taste. In India and other countries, it's a very common method adopted to make the pickle (Kumar, 2019).
7. **Canning:** This process is used to increase the shelf life of food products. It was first discovered by a French confectioner Nicolas Appert in the 19<sup>th</sup> century. The process encompasses cooking the food, and thereafter sealing it in sterilized cans or jars, and then boiling the container for sterilization. This process causes to kill all the microbes under that condition. The process of canning was well explained by Louis Pasteur in 1864, that the food spoilage caused by microbes and the intake of contaminated ones may cause serious health issues. It has been also reported that the, can canned food gets swollen due to gas production due to the decomposition of the foods by the microbes or water produced. It is known to report the anaerobic microbe (*Clostridium botulinum*), produces toxins that may cause food poisoning in the human (Kumar, 2019).
8. **Fermentation:** Some food products such as wine, beer, curd, and cheese are produced by the process of fermentation by using specific bacteria. These fermentative bacteria not only enhance the nutritive values of the food but also protect the food from pathogenic bacteria by producing acid or alcohol. The process of fermentation is carried out by controlled temperature, oxygen level, salt, and other parameters (Kumar, 2019).

## X. MODERN METHODS OF FOOD PRESERVATION

1. **Inhibition:** The main motive of this process is to inhibition of microbial growth. The process relies on the control of the environment (controlled temperature), particular methods of processing (micro structural control), and intrinsic properties (adjustment of pH and water activity). A danger zone is the zone where the growth or chance of microbial growth is maximum and is considered as at the temperature lies between 5 to 60 °C is a danger zone. Thus, storing the food below or above these temperatures keeps the food safe from microbial contact (Rahman, 2007).
  - **Reduction of Water Activity:** Greater the water activity, the greater the chance of microbial contamination or spoilage of foods, until and unless procured a better preservative technique. The water activity of the foodstuff can be reduced by adding some substances (sugar, salts, glycerol, and ethanol) that increase the osmotic pressure. The process of removing the water from foods is commonly done by drying, reverse osmosis, or increasing concentration. The lowering of water activity ( $a_w$ ) influences enzymatic and chemical changes in foods. The  $a_w$  below 0.6 stops bacterial growth (Rahman, 2007; Prokopov & Tanchev, 2007).
  - **Decreased Oxygen:** There are some microbes that thrive in the presence or absence of oxygen. The microbes that grow in the presence of free oxygen are called aerobic microbes, when grow in the absence of free oxygen are called anaerobic microbes,

and those that grow in both conditions are called facultative microbes. The oxygen present in our environment is around 21% whereas in controlled atmospheric storage the oxygen level is reduced to 1-2%, which controls the growth of some microbes (Rahman, 2007; Prokopov & Tanchev, 2007).

- **Carbon Dioxide, Sulphite, Nitrite, and Nitrates:** The normal concentration of CO<sub>2</sub> in the atmosphere is 0.03%, but when increases to 5% in the controlled atmospheric room are effective against Psychrotrophic microorganism which causes spoilage of chilled foods (Gould, 1995). Sulfur dioxide, bisulfite, sulfite, and metabisulphite are generally used in wine, sausage, fruit juice, and other food preservation. The bisulfite has a greater inhibitory effect against fungi and bacterial growth (Tapia de Daza et al., 1996). Nitrite and nitrates with their sodium and potassium salt are generally used in the fermentation of meat products, and the curing of pork and bacon. It also prevents the rancidity of cured meat (Rozum, 1995).
- **Acidification:** Acidification is another accepted method of food preservation. In this method, the acids are used to reduce the pH of food. As the food can be classified into three types. High acidic foods (pH 3.7 to 4.6), medium acidic food (pH 4.6 to 5.3), and non-acidic food (pH 5.3 to 7). So, the microorganism has a particular pH at which they grow. Most bacteria can grow near pH 6.8 and 4 to 8. Few bacteria can grow below pH 4 or above pH 8. Yeast and moulds can grow at a pH of less than 2. Usually, the growth of the microbes decreases with a drop in pH. At the lower pH, the cell is first inhibited and then eventually killed. The degree of microbial inhibition increases as the pH decreases (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Chemical Preservatives:** In this method, anti-microbial chemical agents are used to preserve the foods. Instructed amounts of the chemical are added because excess addition may cause health issues. Common preservatives used are benzoate and benzoic acid which are generally used in acidic foods such as jam, jellies, pickles, soy sauces, and others. Sorbic acid and sorbate are used in cheese, wine, and baked products whereas nitrates and nitrites in meat and propionic and propionates in baked products (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Antioxidants:** Antioxidants are substances that retards or prevent oxidative deterioration and inhibit enzyme-catalyzed reaction, especially the browning of foods by enzymatic and non-enzymatic reactions. Lecithin, ascorbic acid, and tocopherol are the natural antioxidants. There are some antioxidants that are added to the foodstuff namely ethyl gallate, propyl gallate, octyl gallate, Dodecyl gallate, citric acid, tartaric acid, gallic acid, butylated hydroxyanisole, and tertiary butyl hydroquinone (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Surface Coating:** This type of preservative method is not only used to increase the textural appearance but also reduces the water loss from the foodstuffs. The surface coating includes the waxing of apples, oranges, and frozen foods to increase glossiness and reduce shrinkage due to water loss. The formulation of the edible coating of the foodstuff depend on the purpose and the types of the product used.

- **Structure Modification:** There are some chemicals or chemical ingredients are used to modify the structure and functionality of the products. As gums and gel, agar-agar, guar gum, casein, and pectin are used to give the desired structure to the foods to increase the acceptability of the foodstuff. These chemicals are used to provide textural attributes such as the creaminess and oiliness of the formulated products.

## 2. Inactivation

- **Pasteurization:** It is a heat treatment method of food preservation. This method is used to kill a part but not a complete microorganism present in the foods. Usually involves the application of temperature below 100 °C. For example, milk is heated to 63 °C for 30 min or 71 °C for 15 seconds or in ultra-high temperature (UHT), 138 °C for 2-4 seconds. The process of pasteurization is applied to wine, milk, beer, fruit juice, and aerated water (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Sterilization:** This process is more severe than pasteurization. The process involves the use of a combination of high temperature and time to destroy nearly all the microbes present in the food, but this process somehow affects the taste, appearance, texture, and nutritional properties of the food. This method is used to destroy such microbes that destroy at very high temperatures such as the spore of *Clostridium botulinum*. If the correct temperature is not given then there would chance to germinate the spores in the food and cause food poisoning (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Radiation:** This process is known as the food irradiation process. In this process sterilization of food is done by bombarding high energy rays called gamma rays or by moving fast electrons to kill the bacteria, fungi, and other microbes or to delay the fruit ripening. The process is used to stop the sprouting in potatoes and onions. The process is performed after the packaging of foods. Cobalt-60 or Cesium-137 or electron-producing machines are used for ionizing radiation. The unit is rads and measured as kilo rads or megarads (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Electrifying** In this method, a different form of electrical energy is generated to preserve the foodstuffs. Ohmic heating, low electric field stimulation, high-intensity pulsed electric fields, high voltage arc discharge, and microwave heating are commonly used. Ohmic heating is one of the earliest forms. Microwave heating is common and extensively used in every household. Low electric field stimulation is used to control bacterial growth in meat (Rahman, 2007). Pareilleux and Sicard (1970) first coined the mechanism of microbial inhibition by an electric field.
- **High Pressure:** This method gained much attention due to its nonthermal and novelty method of preservation. This method is based on Le Chatelier's principle, according to the principle any reaction, conformational change, or phase of transition is accompanied by decreasing in volume and increasing in pressure. The hydrostatic pressure between the range of 100-600Mpa at room temperature inhibits microbial growth. The vegetative microbial growth can be reduced or inactivated when applied 400-600 MPa, whereas the spores of the same species resist pressure higher than 1000 MPa (Knorr, 1996).



- **Hurdle Technology:** This is the technique where more than one approach is applied to deactivate microbial growth. In this hurdle technique, high temperature is used during processing, lowering redox potential, increasing acidity, the addition of preservatives, and storing at low temperature is used. To control microbial or bacterial spoilage bacteriocin is used, a kind of lactic acid-producing chemical. This method provides safe and secure food free from microbial spoil without any nutritional loss and is also viable economically. The Hurdle technology does not impact sensory attributes also such as texture, smell, and taste of the foods (Kumar, 2019).
- **Nonthermal Plasma:** In this method, the ionized gas flame is exposed over food surfaces such as nitrogen and helium gas, which helps in killing the microbes, if present over the surface (Kumar, 2019).
- **Modified Atmosphere:** In this approach, the atmosphere around the foodstuff is altered. Due to alteration, some nutrients may be lost such as vitamins. This approach is generally adopted to store a large number of foodstuffs. Controlled atmospheric storage is used where the oxygen level is reduced by infusing nitrogen and carbon dioxide gas. The oxygen present in our environment is around 21% whereas in controlled atmospheric storage the oxygen level is reduced to 1-2%. The temperature is adjusted between 0-2 °C, and the humidity is around 95%. The controlling of gases, humidity, and temperature depends on the nature and type of the foodstuffs. With advancing technology, all of these factors are controlled by computers in the controlled atmospheric storage room (Rahman, 2007; Prokopov & Tanchev, 2007).
- **Biopreservation:** When the content of microbes itself present in the food get reduced or replaced by harmful one then the foods get start to spoil. So, the term Biopreservation means the addition of natural microbes or antimicrobials for the preservation of foods or to increase the shelf life of the foods. In this type of preservation method, beneficial bacteria or fermentation products are generally used for controlling or inactivating the pathogenic bacteria. The most commonly used bio preservatives are lactic acid, Acetic acid-producing bacteria, and bacteriocin (Kumar, 2019).

### 3. Recontamination

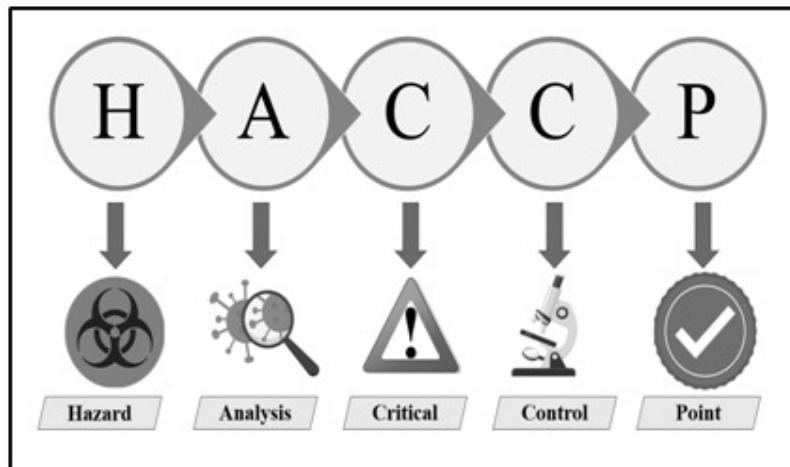
- **Packaging:** In this method, the food is stored in a plastic bag, and a vacuum is created inside the bag by sucking air using a vacuum pump before sealing the bag. Under this the microbial growth is retarded because for the survival of the microbial, they need oxygen. This method is generally used for nuts, dates, and other dry fruits packaging to keep them fresh without losing their flavour. Packaging is generally adapted to make and maintain the food in a fresh and quality way, throughout the entire distribution chain until it is eaten. Packaging is not only used to preserve, store, and maintain freshness and quality but also it provides to keep the sensory attributes of the food in a good way, also to display the active compounds present in the food, and also to provide technological information to the consumers. The new packaging provides more efficient oxygen, CO<sub>2</sub>, and water vapor barrier properties and also increases the shelf life of the products. Different types of packaging are: Modified

atmosphere packaging, controlled atmosphere storage, vacuum packaging, edible films and coating, active packaging, and smart packaging (Gomes et al., 2023).

- **HACCP:** Hazard Analysis Critical Control Point (HACCP) is a systematic, science-based approach used in food production to ensure food hygiene and safety. It is not only based on the end stage of the food testing and inspection but involves the continuous approach to food safety to identifying, examining, analyzing, evaluating, and establishing corrective measures and controlling the hazards at every stage of food production. This is why it is a unique and effective method (Mortimore & Wallace, 2013).

**The following points need to keep in mind regarding HACCP**

- It identifies and measures the hazard at any stage of production, right from start to finish.
- It determines the critical control points.
- It requires an evaluate the critical limits and procedure to monitor each critical point.
- It establishes the corrective procedure.



**Figure 5:** Steps involve in HACCP

## XI. RECENT ADVANCES IN FOOD PRESERVATION

1. **Bioinspired Spray Coating:** Microbial spoilage and food safety concern enhanced the idea of sustainable food-active packaging material, making the development of bioactive spraying coating to preserve the foods basically the raw fruits. This bioactive spraying contains carboxymethyl cellulose nano-fibers. The most important characteristic of biohybrid nanofibers is that it mimics oxidase-like and apyrase-like activities. These activities enable effective enzyme-like sterilization as usually happens in raw or unplugged fruits. These biohybrid nanofibers effectively work against (killing rates 90.46%) *Staphylococcus aureus*, *Escherichia coli* 0157, and methicillin-resistant *Staphylococcus aureus*. This type of advanced technique provides food storage

for 12 days (for banana and mango types of fruit). This type of technique can be applied to food, biomedicine, and agricultural field (Huang et al., 2023).

2. **Edible Films:** The edible films are prepared from Asian plant extracts and essential oils enriched with antioxidants and antimicrobial properties. These ingredients help to protect the fruits or vegetables against microbial contamination or growth. However, the information on the utilization of these films is limited, but the Asian plant extract and essential oils when applied to packaging, demonstrated that it increases the shelf life or storage duration of the foods as it helps in preserving the pH, lipid oxidation, and color of the foods as it in the natural form (Kong et al., 2023).
3. **Liposome as Anti-Fungal:** A liposome encapsulated with *Syzygium aromaticum*, *Zingiber officinale*, *Curcuma longa*, *Cinnamomum verum*, and *Laurus nobilis* extract prepared by using as a lipid phase of phosphatidylcholine extract. These extracted liposomes showed prominent anti-fungal activity against *Penicillium* sp. and *Aspergillus* sp. with an efficacy rate of 86-92%. Among this variation, the Curcuma-longa-filled liposome showed the highest efficacy after freeze dry-rehydration, and freeze-thaw storage treatment (Aslan et al., 2023).
4. **Citric Acid Biopolymeric Films:** The green cross-linking technology is assumed to be an effective technique to increase the biopolymeric food packaging film, among which the citric acid coating film is popular. The citric acid biofilm is gently applied in various ways such as polysaccharide-based, biopolyester-based, and protein-based biopolymers. The cross-linking process is gently influenced by altering pH and temperature (Zhang et al., 2023).
5. **Whey-Based Emulsion Coating:** To remain fresh cut one fruit, there needs an edible and water-resistant coating. Sunflower oil and transglutaminase have water-resistant characteristics, mechanical properties, and microstructure by whey protein-based film. It helps to preserve the fruits (cutapples) in a fresh way. The study suggests that the application of 1.5% w/w sunflower oil significantly interacts with alpha and beta-lactoglobulin and its dimer to create an emulsion droplet that can be dispersed throughout the protein film. These help to maintain the mechanical properties, microstructure, and water resistance. This type of whey emulsion significantly reduces browning and weight loss by 46% and 26% in fresh-cutted apples (Xin et al., 2023).

## XII. CONCLUSION

The foods in their natural form resist infection and microbial attack by the healthy cells present inside them. So, any adverse changes in food quality such as taste, texture, appearance, aroma, and flavour along with nutritional value, shelf-life, and safety may cause spoilage of foods. The deterioration of foods depends on the type of food and their rapid or slow deterioration, and if not controlled might be dangerous for health. Utmost of our food is comprised of plant and animal products, which are generally seasonal and spoil quickly. The harvested, caught, slaughtered, or manufactured products from those progressively goes deteriorates or spoiled until and unless it is preserved within the time. This deterioration is either caused by the production of toxic substances by microbes or the loss of nutritional value. The main aim of food storage is to guarantee safe and high-quality food. The proper

storage of food increases the shelf life of the food, which basically depends on the type, packaging, and storage conditions such as humidity and temperature. The main aim of the chapter is to make aware of the term food spoilage, and food preservation, and to understand food based on perishability, and the different methods of food preservation (conventional and modern methods). The book chapter elaborately explained the recent advances used in food preservation.

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