UNIT 3: FOOD SPOILAGE AND FOOD PRESERVATION

Spoilage is a natural phenomenon and all foods undergo varying degrees of deterioration or spoilage. Spoilage may include losses in organoleptic desirability, nutritional value, safety and aesthetic appeal.

Food is subject to physical, chemical and biological deterioration. The highly sensitive organic and inorganic compounds, which make up food and the balance between these compounds, and the uniquely organised structures and dispersions that contribute to texture and consistency of unprocessed and manufactured products are affected by nearly every variable in the environment.

3.1 TYPES OF SPOILAGE

The food may become unacceptable to the following factors:

a) Growth and activities of microorganisms principally bacteria, yeasts and moulds (This is by far the most important and common cause of food spoilage).
b) Activities of food enzymes (enzymatic browning is a common example).
c) Infestation by insects, parasites and rodents.
d) Chemical changes in a food (i.e. not catalysed by enzymes of the tissues or of microorganisms).
   For example: The chemical oxidation of fats producing rancidity as well as non-enzymatic browning reactions in foods like Maillard Browning.
e) Physical changes or damages such as those caused by freezing (freezer burn), by drying (caking) etc.
f) Presence of foreign bodies.
g) Physical abuse i.e. contamination with chemical agents.

Thus, all the types of spoilage changes can be broadly categorised into physical, chemical and microbiological types. On other hand, the food can be categorised into following three groups:

i) Stable or non – perishable foods
ii) Semi perishable foods
iii) Perishable foods

The concept of a spoiled food is subjective and associated with individual taste. Personal preferences, ethnic origin and family background may play a role in an individual deciding whether a food is spoiled. The chemical and bacteriological changes associated with hanging game make the food unacceptable for some consumers but a delicacy for others. Bananas that have become brown and sugary are considered overripe and therefore spoiled to many consumers but are perfectly acceptable to some.

3.2 ROLE OF MICROORGANISMS

Microbial spoilage of foods is the beginning of the complex natural process of decay that under natural circumstances leads to recycling of the elements present in the animal or plant tissues in the natural environment.

3.2.1 Contamination of living plants and animals

The internal tissues of healthy plants and animals are essentially sterile including in the case of animals body fluids such as blood. Plants have a natural microflora associated with the surfaces of roots, stems, leaves, flowers

and fruits. Invasion of healthy tissues and subsequent growth of microorganisms is prevented by:

a) Outer mechanical barriers, e.g. epidermis with an outer waxy layer, and outer corky layers
b) Internal chemical constituents that are anti-microbial, e.g. tannins, organic acids and essential oils;
c) Inert cell walls welded into tissues that are difficult to penetrate;
d) Active cells with intact membranes.

Plant materials are harvested in the living state and, as long as the mechanical barriers remain intact, can remain in storage for several months without spoilage.

Animals have a natural microflora associated with the skin, the gut content and external openings, e.g. the mouth. Lymph nodes and liver may also be contaminated with invading microorganisms. Invasion of healthy tissues and subsequent growth of microorganisms is prevented by:

i) Epithelial barriers e.g. stratified skin epithelium and intestinal mucosa;
ii) The immune system consisting of the lymphatic system, white blood corpuscles and antibodies;
iii) Active cells with intact membranes;
iv) Presence of natural antimicrobials, e.g. lyso-zyme in tears, saliva and egg white;
v) Voiding mechanisms such as vomiting.

Once an animal or plant is dead the activity of the majority of factors that prevent microbial invasion of tissues by microorganisms ceases and invasion is only temporarily hindered by mechanical barriers such as stratified epithelium

or plant epidermis. Cell membranes are no longer active and leak cell contents, providing nutrients for microbial growth.

3.2.2 Sources of Potential Spoilage Organisms In Foods

The natural microflora of living plants and animals is only one source of microorganisms associated with spoilage. The natural microflora can be added to in a number of ways, as shown in Fig.1.

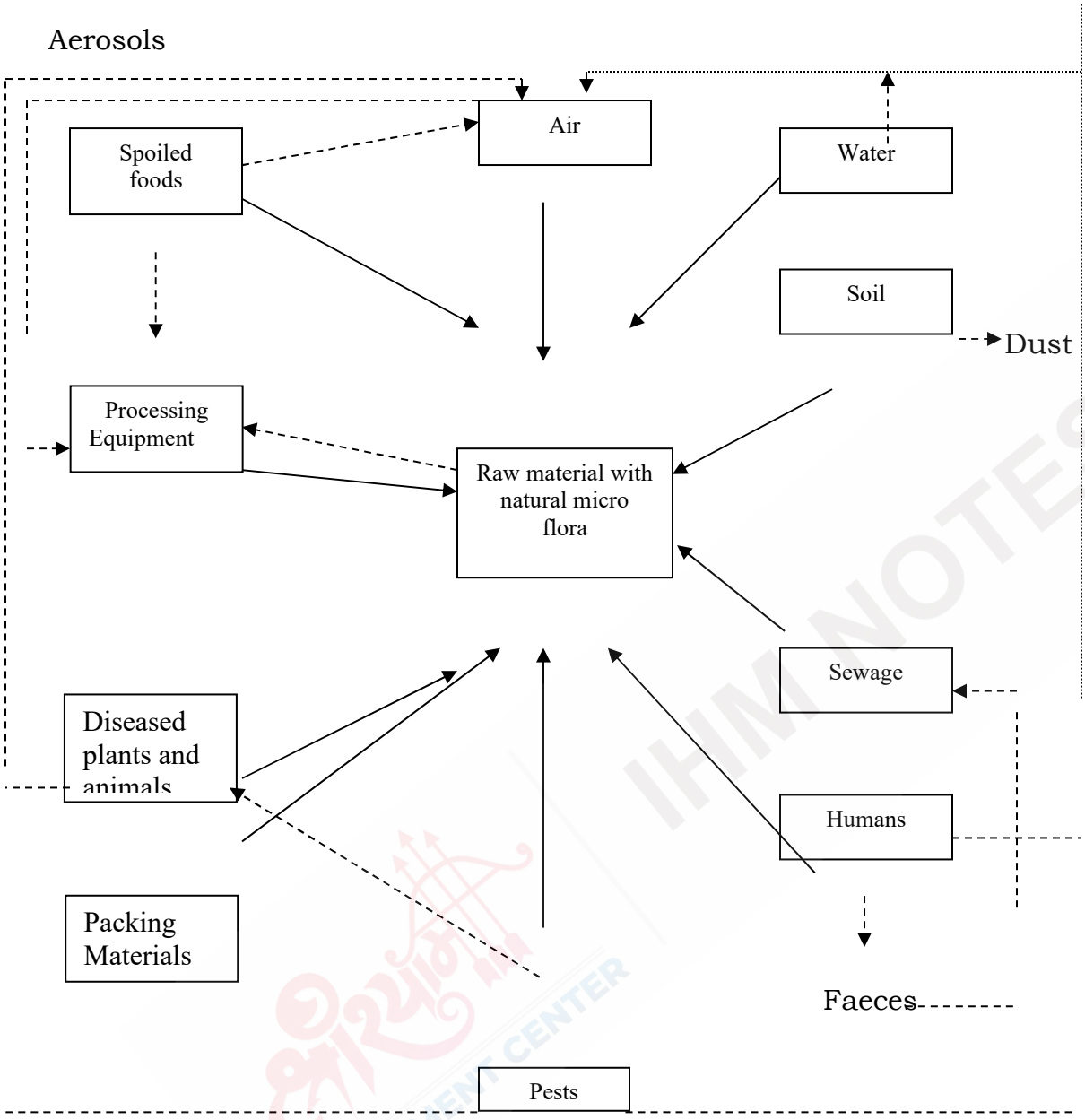

Fig. 3.1 Sources of contamination of food.

3.2.3 Growth of Microorganisms

Microorganisms grow rapidly; we call it logarithmic growth. The time a bacteria takes to multiply is known as its generation time.

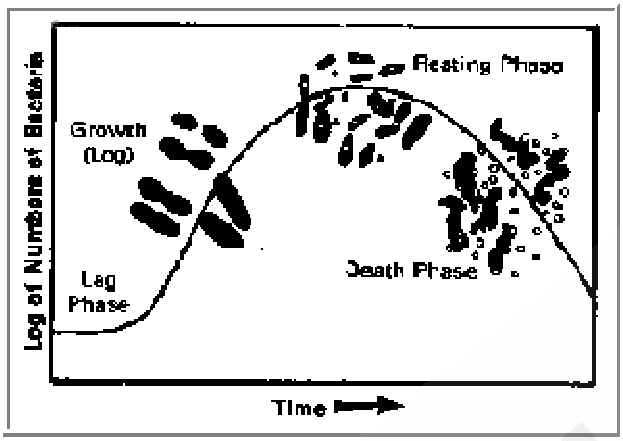

Figure 2 shows a typical growth curve. Four distinct phases occur in the growth curve: lag; log or growth phase; stationary phase and death phase.

Bacteria need about four hours to adapt to a new environment before they begin rapid growth. In handling food, this means we have less than four hours to make a decision to either cool the food, heat it, or eat it. For example, when chickens arrive at the dock of a fast food outlet, or at a restaurant or at your home, you must decide whether to heat and eat them, to refrigerate them at a low temperature (chickens freeze at –2.2° C) for a short period of time, or whether to wrap and freeze the chicken for a longer period of time. If you don't decide, the bacteria will enter the log phase of growth where bacteria grow rapidly and cause food to spoil. Bacteria produce the slime, toxins, off colors and odors associated with food spoilage in the log phase of growth (refer Fig 3.3). Remember, the four hours bacteria remain in the log phase is approximate and cumulative.

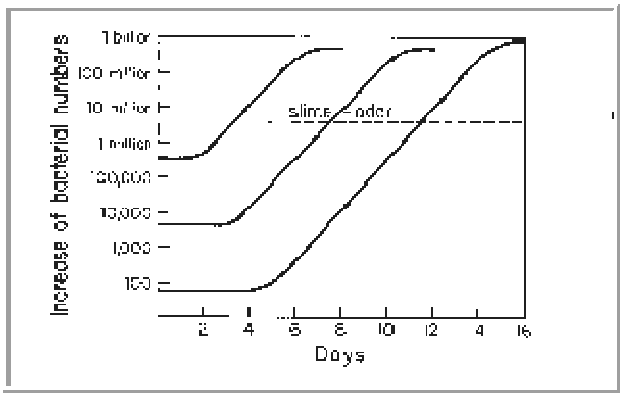

Fig 3.3

As microorganisms grow, they tend to form colonies. These colonies are made up of millions of individual cells. Once a colony forms, the food available to each cell is limited and excretions from these millions of cells become toxic to a microbe. This is the stationary phase. Some of the cells now begin to die. If we can control bacterial growth, we can control the major cause of food spoilage.

3.4 DIFFERENT TYPES OF FOOD SPOILAGE

Food undergoes different types of spoilage depending on his composition as seen in the Tables 3.1 and 3.2.

Table 3.1: Types of food spoilage

Food	**Type of spoilage**	**Microorganisms involved**
Bread	Moldy	***Rhizopus nigerians*** *Penicillium* *Aspergillus niger*
	Ropy	*Bacillus subtilis*
Maple sap and Syrup	Ropy	*Enterobacter aerogenes*
	Yeasty	*Saccharomyces* *Zygosaccharomyces*
	Pink	*Micrococcus roseus*
	Mouldy	*Aspergillus*
Fresh fruits and vegetables	Soft rot	*Rhizopus* *Erwina*
	Gray mould rot	*Botrytis*
	Black mould rot	*Aspergillus niger*
Pickles, saurekraut	Film yeasts, Pink yeasts	***Rhodotorula***
Fresh meat	Putrefaction	*Alcaligenes* *Clostridium* *Proteus vulgaris* *Pseudmonas fluorescens*
Cured meat	Mouldy	*Aspergillus* *Rhizopus* *Pencillium*

	Souring Greening, slime	*Pseudomonas* *Micrococcus* *Lactobacillus* *Leuconostoc*
Fish	Discoloration Putrefaction	*Pseudomonas* *Alcaligenes* *Flavobacterium*
Eggs	Green rot Colourless rot Black rot	*Pseudomonas* *fluorescens* *Pseudomonas* *Alcaligenes* *Proteus*
Concentrated Orange juice	Off flavour	*Lactobacillus* *Leuconostoc* *Acetobacter*
Poultry	Slime, odour	*Pseudomonas* *Alcaligenes*

Table 3.2 Microbiology of Canned Food Spoilage

Types of product	**Types of Spoilage Organisms, with examples**	**Signs of Spoilage**	
		Can	**Contents of Can**
Low and medium products, pH above 4.6, e.g., corn, peas,	Flat sour (*Bacillus stearothermophilus*)	Possible loss of vacuum on storage	Appearance not usually altered; pH markedly lowered; sour;

spinach, asparagus	Thermophilic anaerobe (*Clostridium thermosaccharolyti-cum*) Sulfide spoilage (*Clostridium nigrificans*) Putrefactive anaerobe (*Clostridium sporogenes*) Aerobic sporeformers (odd types) (*Bacillus spp.*)	Can swells, may burst Can flat, hydrogen sulfide gas absorbed by the product Can swells, may burst Usually no swelling, except in cured meats when nitrate and sugar are present	may have slightly abnormal odor; sometimes cloudy liquor Fermented, sour, cheesy, or butyric odor Usually blackened, " rotten egg" odor May be partially digested; pH slightly above normal; typical purtrid odor; may be toxic Cogulated evaporated milk, black beets
Acid products, pH	Flat sour (*Bacillus*	Can flat, little	Slightly pH

below 4.6, e.g., tomato juice, fruits, and fruit juices	*thermoacidurans*) Butyric anaerobes (*Clostridium butyricum*) Non sporeformers (mostly lactic acid types of bacteria) Yeasts Molds	change in vacuum Can swells, may burst Can swells, usually burst, but swelling may be arrested Can swells, may burst Can flat	change; off odor and flavour Fermented, butyric odor Acid odor Fermented; yeasty odor Surface growth; musty odor

3.5 BASIC PRINCIPLES OF FOOD PRESERVATION

1. Prevention or delay of microbial decomposition.
   (a) By keeping out microorganisms (asepsis)
   (b) By removal of microorganisms, e.g., by filtration
   (c) By hindering the growth and activity of microorganisms e.g., by low temperatures, drying, anaerobic conditions, or chemicals
   (d) By killing the microorganisms e.g., by heat or radiation

2. Prevention of delay of self-decomposition of the food
   (a) By destruction or inactivation of food enzymes e.g., by blanching
   (b) By prevention or delay of purely chemical reactions e.g., prevention of oxidation by means of an antioxidant

3. Prevention of damage because of insects, animals, mechanical causes, etc.

Yet, the principles underlying methods of preservation used in the past are still the same as today. They can be summarized as:

- Chill or freeze food to retard growth of micro-organisms and inhibit enzyme activity, e.g. frozen pizza
- Heat food to destroy micro-organisms and prevent enzyme activity, e.g. pasteurized milk
- Place food in an acidic or alkaline solution to inhibit growth of micro-organisms, e.g. pickled onions
- Place food in a sugary or salty solution to make water unavailable to micro-organisms, e.g. jam
- Keep food in airtight containers to deprive micro-organisms of oxygen and prevent further contamination, e.g. canning
- Modifying the atmosphere in the packaging of a food product, e.g. bacon.
- Reduce moisture content of food to make water essential for growth unavailable to micro-organisms, e.g. grapes to raisins
- Use fermentation, producing food products with extended shelf life, e.g. milk to cheese

Using any one or combination of the following methods can control the deterioration of food:

a) Pickling

Pickling vegetables and fruits with vinegar prevents the growth of microorganisms. This is due to the food being placed in a low pH solution in which microorganisms cannot grow.

b) Fermentation

Fermentation is the use of biological processes to make products. Its major uses are in the production or preservation of food. Fermentation is not new. For many centuries fermentation has used microorganisms to make beer, yogurt and cheese. The basis of the fermentation process is the conversion of glucose (sugar) to alcohol or to lactic acid by enzymes. Fermentation acts as a preservation method by producing an acid, which lowers the pH of the product, converting a perishable food into one that has a longer shelf life, e.g. fresh milk to cheese.

c) Addition of sugar or salt

The addition of large quantities of sugar inhibits the growth of microorganisms by making water unavailable. Jams, marmalades and jellies use this principle in their manufacture.

Coating food in salt or placing it in a salt solution (brine) reduces the moisture content of the food; i.e. it reduces the availability of water to microorganisms. With little moisture, microorganism growth is retarded. However, the taste of the food may well be changed considerably.

d) Dehydration

Microorganisms need water in order to grow and multiply. When moisture is reduced in food, microorganism growth is retarded. Dehydration reduces the water activity level, weight and bulk of the food and helps to preserve the product.

The main principle behind dehydration is the reduction of water to prevent microorganism activity. Many products, such as vegetables, are diced before drying to increase their surface area and making water loss more rapid. Blanching may be necessary to inactivate enzymes that cause browning.

Sun drying is one of the most traditional methods of drying. It is slow and only practical in hot, dry climates. The food may be vulnerable to contamination through pollution and vermin, e.g. rodents and flies. Other forms of drying foods have been developed in the food industry, these are usually suitable for particular types of products. For example:

i) Spray drying: suitable for dried milk and coffee powder. A fine spray of liquid is injected into a blast of hot air in a chamber. Water evaporates in seconds, leaving the solid part of the product behind in a powdered form.
ii) Tunnel drying: hot air is blown over a food in a tunnel, e.g. vegetable pieces.

e) Pasteurisation

The process of pasteurisation extends the shelf life of foods a little by killing most food spoilage organisms and pathogenic organisms by the application of heat. Food products that have been pasteurised , extend their shelf life by several days and are usually stored in refrigerated conditions, e.g. fresh milk. This type of product would have a 'use by' date mark on its label.

f) Sterilisation

The process of sterilisation uses a combination of high temperature and time to destroy nearly all microorganisms in food. This process is more severe than pasteurisation, and can sometimes affect the appearance and taste of the food.

This is important as some microorganisms can form spores, which have the ability to survive at high temperatures. If the correct temperature is not reached there is the possibility that the spores will germinate and grow and food poisoning could result. Some organisms can survive the sterilisation process if not processed for enough time or at a high enough temperature, e.g. *Clostridium botulinum*.

The time and temperature at which foods are sterilised depend on the type of can used, and the density of the food product. For example, soup heats very quickly as the liquid helps transfer the heat by convection, whereas canned corned beef would heat through at a slower pace, as the heat needs to penetrate the product by conduction. Food products that have been sterilised have a very long shelf life and are stored at ambient (room) temperature, e.g. canned ham or long-life milk. These types of products would have a 'best before' date mark on the label.

g) Canning

The process of canning aims to destroy microorganisms and their spores through the application of heat. This is achieved by sterilising food within airtight containers to prevent re-contamination.

Food products that have been canned have very long shelf life and are stored at ambient (room) temperature, e.g. canned baked beans. Canned products would have a 'best before' date mark on the label.

h) Irradiation

The process of irradiation is the process of exposing food to carefully controlled amount of ionising energy. Irradiation is used to:

- Inhibit sprouting of vegetables
- Delay ripening of fruits
- Reduce numbers of micro-organisms which cause food spoilage or poisoning, e.g. salmonella in poultry and *Escherichia coli* O157:H7 in red meat

i) Freezing

Freezing is based on two principles:

(i) Very low temperatures, which inhibit growth of microorganisms and retard enzymatic and chemical activity

(ii) The formation of ice crystals, which draw available water away from food, therefore preventing the growth of microorganisms

Blanching may be necessary to inactivate enzymes that cause browning. In a domestic situation, food is frozen by placing it in a freezer and allowing heat transfer by conduction (i.e. the removal of heat from the food). This process can take several hours, depending on the nature of the food being frozen.

Other forms of freezing have been developed in the food industry to speed-up the freezing time. This ensures that products are frozen in the shortest time possible, reducing the risk of microorganism growth. Three methods are:

- ***Blast freezing:*** Batches of food are subjected to a constant, steady stream of cold air (-40 ^{c}o or lower) in a tunnel or cabinet.
- ***Scraped heat exchange:*** Products, such as ice cream, are frozen using this method in to reduce the formation of large ice crystals. The product is scraped against a cooled surface and then immediately scraped away.

- ***Cryogenic freezing***: Liquid nitrogen (or carbon dioxide) is sprayed directly onto small food items such as soft fruits or prawns. Due to the liquid's extremely low temperatures (-196 ^{c}o and –78 ^{o}C respectively), freezing is almost instant.

j) Modified Atmosphere Packaging

Modified Atmosphere Packaging is the enclosure of food in a package in which the atmosphere has been changed by altering the proportions of carbon dioxide, oxygen, nitrogen, water vapour and trace gases. The process retards microbial and biochemical activity. Products such as bacon, red meat, poultry, vegetables and bakery products use this method to increase shelf life by retarding microorganism growth.

Food spoilage is caused by microbial growth in foodstuffs, chemical reactions within the food itself or between the food and its environment, or the presence of foreign material in the food. Practicing the following can slow spoilage :

- Package the freshest possible product.
- Use good sanitation and personal hygiene habits when processing and packaging food.
- Use the best possible packaging material for the length of time the food remains in the market channel.
- Cool processed or cooked foods as quickly as possible to below 5 ^{o} C.
- Keep foods covered .