UNIT 2 FOOD CONTAMINATION AND SPOILAGE

Structure

2.0 OBJECTIVES

After reading this Unit, we shall be able to:

- identify sources of food contamination;
- specify food spoilage – its types, causative agents and changes associated with it;
- enumerate factors affecting the rate of spoilage; and
- explain principles and methods of food preservation.

2.1 INTRODUCTION

Most foods are excellent media for rapid growth of micro-organisms. There is abundant organic matter in foods, their water content usually sufficient, and the pH is either neutral or slightly acidic.

Foods consumed by man and animals are ideal ecosystems in which bacteria and fungi can multiply. The mere presence of micro-organisms in foods in small numbers however, need not be harmful, but their unrestricted growth may render the food unfit for consumption and can result in spoilage or deterioration. There are many opportunities for food to become contaminated as it is produced and prepared. Many food borne microbes are present in healthy animals (usually in their intestines) raised for food. Meat and poultry carcasses can become contaminated during slaughter by contact with small amounts of intestinal contents. Similarly, fresh fruits and vegetables can be contaminated if they are washed or irrigated with water that is contaminated with animal manure or human sewage. Some types of *Salmonella* can infect a hen's ovary so that the internal contents of a normal looking egg can be contaminated with *Salmonella* even before the shell in formed. Oysters and other filter feeding shellfish can concentrate *Vibrio* bacteria that are naturally present in sea water, or other microbes that are present in human sewage dumped into the sea.

Later in food processing, other food borne microbes can be introduced from infected humans who handle the food, or by cross contamination from some other raw agricultural products. For example, *Shigella* bacteria, hepatitis A virus and Norwalk virus can be introduced by the unwashed hands of food handlers who are themselves infected. In the kitchen, microbes can be transferred from one food to another food by using the same knife, cutting board or other utensil to prepare both without washing the surface or utensil in between. A food that is fully cooked can become recontaminated if it touches other raw foods or drippings from raw foods that might contain pathogens microbes responsible for spoilage.

The way in which food is handled after it is contaminated can also make a difference in whether or not an outbreak occurs. Many bacteri need to multiply to a large number before enough are present in food to cause disease. Given warm moist conditions and an ample supply of nutrients, a bacterium that reproduces by dividing itself every half hour can produce 17 million progeny in 12 hours. As a result, lightly contaminated food left out overnight can be highly infectious by the next day. If the food is refrigerated promptly, the bacteria multiply at a slower rate. In general, refrigeration or freezing prevents virtually all bacteria from growing and multiplying but generally preserves them in a state of suspended animation. This general rule has a few surprising exceptions. Two food borne bacteria, *Listeria monocytogenes* and *Yersinia enterocolitica* can actually grow at refrigerator temperatures.

2.2 FOOD CONTAMINATION

Food contamination is **the introduction or occurrence of a contaminant in food.** A contaminant is any biological or chemical agent, foreign matter, or other substance unintentionally added to food that may compromise food safety or suitability. Among these contaminants are biological, chemical or physical agents in, or condition of, food with the potential to cause an adverse health effect.

The contamination of food by chemicals is a worldwide public health concern and is a leading cause of trade problems internationally. Contamination may occur through environmental pollution, as in the case of toxic heavy metals, Poly Chlorinated Biphenyl (PCBs) and dioxins, or through the intentional use of chemicals, such as pesticides, animal drugs and other agrochemicals. Food additives and contaminants resulting from food manufacturing and processing can also adversely affect health. When foods are contaminated with unsafe levels of pathogens, chemical contaminants, or metals, they can pose substantial health risk to consumers and place severe economic burden on individual communities or nation.

Cross-contamination of food is a common factor in the cause of food borne diseases. Cross-contamination is the contamination of a food product from another contaminated source. Foods can become contaminated by micro-organisms (bacteria and viruses) from many different sources during the food preparation and storage process. There are three main ways cross-contamination can occur:

- Food to food
- People to food
- Equipment to food

2.2.1 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 micro flora associated with the surfaces of root, stem, leaves, flowers and fruits. Invasion of healthy tissues and subsequent growth of micro-organisms is prevented by:

- Outer mechanical barriers, e.g. epidermis with an outer waxy layer, and outer corky layers;
- Internal chemical constituents that are anti-microbial, e.g. tannins, organic acids and essential oils;
- Inert cell walls welded into tissues that are difficult to penetrate;
- 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 at low temperature for several months without spoilage.

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

- Epithelial barriers e.g. stratified skin epithelium (epidermis) and intestinal mucosa;
- The immune system consisting of the lymphatic system, white blood corpuscles and antibodies;

- Active cells with intact membranes;
- Presence of natural antimicrobials, e.g. lysozyme in tears, saliva and egg white;
- Voiding mechanisms such as vomiting.

Once an animal or plant is dead the activity of the majority of factors (defense mechanisms) that prevent microbial invasion of tissues by micro-organisms 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.

2.2.2 Sources of Food Contamination

It helps to understand at which point our food might become contaminated, as this will provide us with a better impetus for taking personal responsibility to reduce the potential for further contamination. There are five main events that can cause food contamination:

i) **Food production**: The use of chemicals, fertilizers, manures etc. all have the potential to contaminate food as it is being grown.

ii) **Environmental factors**: Bacteria, parasites, fungal sporus etc. travel in the wind, float in the water, hitch lifts with dust and reside snugly in the soil. They are a part of nature's web of life and will always be a possible source of contamination if not dealt with appropriately as part of a consistent and dedicated approach to food hygiene.

iii) **Food processing**: Whether in a large factory or in your own kitchen, food processing can be a major source of contamination. Areas used for processing need to be kept scrupulously clean or cross-contamination can easily occur, especially with meat products (natural bacteria residing in the intestines of animals are a major source of cross-contamination when mishandled).

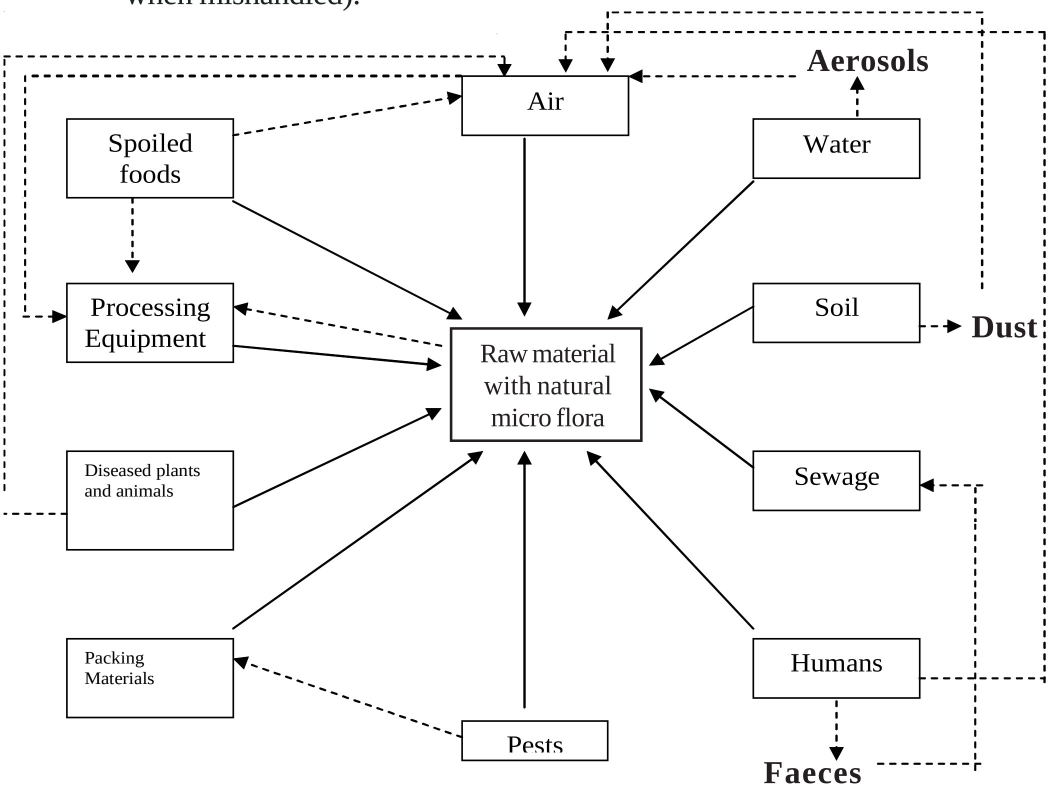

Fig. 2.1: Sources of contamination of food

iv) **Food storage**: Food that is stored incorrectly, for instance an uncooked chicken thigh resting next to a bunch of grapes, can be a source of transferring bacteria and other contaminants from one food to another.

v) **Food preparation**: A great deal of food contamination occurs during the preparation stage. A sick person can pass on germs, ranging from flu to gastroenteritis. A chopping board used for meat that is not washed and then used for vegetables is another source of possible contamination. Unwashed hands, dirty kitchen spaces, insects and rodents in the kitchen etc. are all possible sources of food contamination.

2.3 FOOD SPOILAGE

Spoilage of food may be due to chemical or biological causes; the latter include action of inherent enzymes, growth of micro-organisms, invasion by insects, and contamination with trichinae and worms. About one-fourth of the world's food supply is lost through the action of micro-organisms alone.

The "spoilage" concept includes concepts about edibility, means the food is unfit to eat or fit to eat. Spoilage is decomposition. Many foods may not be decomposed, but harbor certain kinds of bacteria, or their toxins, in number or amounts which make the food poisonous and thus unfit for human consumption.

The criteria for assurance in foods suitable for consumption are:

- The desired stage of development or maturity of the food.
- Freedom from pollution at any stage in the production and subsequent handling of the food.
- Freedom from objectionable, chemical and physical changes resulting from action of food enzymes; activity of microbes, insects, rodents, invasion of parasites; and damage from pressure, freezing, heating, drying, and the like.
- Freedom from micro-organisms and parasites causing food borne illnesses.

Enzymatic and microbial activities are undesirable when they are unwanted or uncontrolled. An example is the souring of milk; if unwanted, it is spoilage, yet the same process is purposely used in the production of certain cheeses and other fermented products made from milk.

2.3.1 Types of Spoilage

The food may become unacceptable due to the following factors:

1) Growth and activities of micro-organisms principally bacteria, yeasts and moulds (***This is by far the most important and common cause of food spoilage*).**

2) Activities of food enzymes (enzymatic browning is a common example).

3) Infestation by insects, parasites and rodents.

4) Chemical changes in a food (i.e. not catalyzed by enzymes of the tissues

or of micro-organisms). For example the chemical oxidation of fats producing rancidity as well as non-enzymatic browning reactions in foods like Maillard Browning.

5) Physical changes or damages such as those caused by freezing (freezer burn), by drying (caking) etc.

6) Presence of foreign bodies.

2.3.2 Classification of Foods on the Basis of Stability

Foods are frequently classified on the basis of their stability as nonperishable, semi perishable, and perishable. An example of the first group is sugar. Few foods are truly nonperishable. Hermetically sealed, heat-processed, and sterilized (canned) foods are usually listed among the nonperishable items. For all intents and purposes, they belong there. However, canned food may become perishable under certain circumstances, when, by accident, there is a chance for recontamination following processing because of faulty seams of the cans, or through rusting or other such damage so that the can is no longer hermetically sealed.

Classified as semi perishables are usually the dry goods, such as flour, dry legumes, baked goods, hard cheeses, dried fruits and vegetables, and even waxed vegetables. Frozen foods, though basically perishable, may be classified as semi perishables provided they are freezer-stored properly.

The majority of our food materials must be classified as perishables. This group includes meat, poultry, fish, milk, eggs, many fruits and vegetables, and all cooked or “made” food items, except the dry and very acid ones.

2.4 ROLE OF MICRO-ORGANISMS

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.

2.4.1 Micro-organisms involved in Spoilage

Micro-organisms which may cause food to spoil include molds, yeasts, and bacteria. The contamination with molds, as a rule, is easily detected because of the presence of furry hyphae or threadlike structures which, in many instances, are colored. They often contribute a musty odor and flavor to the food they invade. Some molds, because of toxins they produce, are not altogether harmless. Semi moist foods or foods with low water activity having been partially dehydrated, and where the remaining water is sufficiently bound to hold the growth of bacteria are ideal for contamination by molds and yeasts.

Yeasts are unicellular organisms of small sizes which multiply by budding. In general, sugars are the best food source for energy for yeast; Carbon dioxide and alcohol are the end products of the fermentation mediated by yeats. Spoilage due to yeast may usually be recognized by the presence of bubbles and an alcoholic smell and taste.

Bacteria spoil food in many ways and it is not always possible to recognize the spoilage by sight, smell, or taste. Unfortunately, some of the bacteria that are important from a public health point of view may multiply to dangerously high numbers in food without changing the appearance, odor, or taste of the food. Disease-producing food has usually no decomposed appearance, but is certainly unfit for human consumption, and must be considered to be spoiled.

It is an important fact that almost any food will spoil if it is moist and not kept frozen. Spoilage must be expected within a wide temperature range. The various types of micro-organisms as well as the genera, species, and strains vary in their temperature and food requirements. Thus the bacterial flora of a spoiled food item will vary greatly.

The origin of micro-organisms also varies. The micro-organisms may include the original flora of the particular food, as well as contaminants added during handling, processing, transporting, storing, preparing, and serving.

2.4.2 Growth of Micro-organisms

The multiplication of spoilage organisms on or in the food materials depends on many factors – the type of organism involved, its ability to gain nourishment from the food, competition from other micro-organisms, initial load, and environmental conditions. Micro-organisms grow rapidly; we call it logarithmic growth. The time a bacterium takes to multiply (double its number) is known as its generation time.

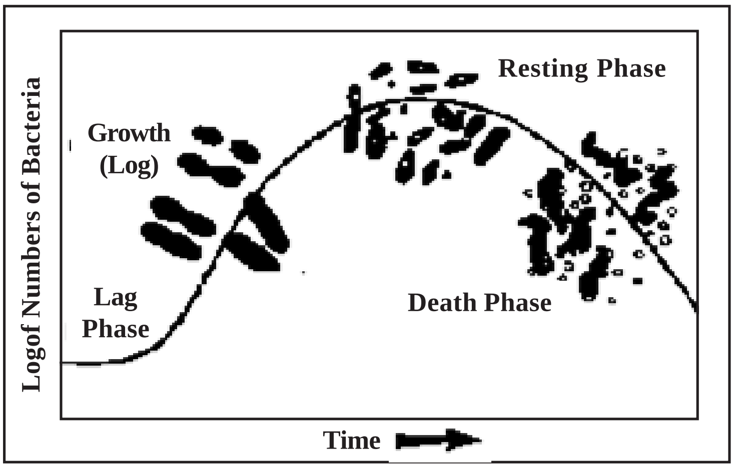

Fig. 2.1: A typical bacterial growth curve

Four distinct phases occur in the growth curve: lag; log or growth phase; stationary phase and death phase (Fig. 2.1). 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.

As micro-organisms 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.

The multiplication of spoilage organisms on or in the food materials depends on many factors – the type of organism involved, its ability to gain nourishment from the food, competition from other micro-organisms, initial load, and environmental conditions.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1) What are spoilage bacteria?

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2) Classify foods on the basis of their stability.

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3) What are the types of food spoilage?

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4) What causes food spoilage?

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2.5 FACTORS AFFECTING SPOILAGE

Food is a chemically complex matrix, and predicting whether, or how fast, micro-organisms will grow in any given food is difficult. Most foods contain sufficient nutrients to support microbial growth. Several factors encourage, prevent or limit the growth of micro-organisms in foods; the most important are water activity a_w, pH and temperature.

Factors affecting microbial growth are divided into two groups -intrinsic and extrinsic parameters (Table 2.1). These factors affect the growth of micro-organisms on foods. When spoilage of a food occurs under a given set of circumstances, not all of the different types of organisms contaminating a food are associated with the spoilage process. In fact, the spoilage flora always is dominated by just a few and sometimes only one organism. Components of the micro flora compete with one another for the available nutrients and the organism(s) with fastest growth under a particular set of circumstances will become dominant and give rise to the spoilage symptoms.

Table 2.1: Intrinsic and Extrinsic Parameters Affecting Microbial Growth

Intrinsic parameters	**Extrinsic parameters**
Water activity, humectant identity	Temperature
Oxygen availability	Relative humidity
pH, acidity, acidulant identity	Atmospheric composition
Buffering capacity	Packaging
Available nutrients	
Natural antimicrobial substances	
Presence and identity of natural microbial flora	
Colloidal form	

The component of the micro flora which becomes dominant is determined by a complex interaction between the components of the contaminating micro flora (implicit factors), the storage environment (extrinsic factors) and the physico-chemical properties of the food (intrinsic factors).

All of the factors that influence the growth of micro-organisms have been dealt with as under. Time is included because, under any given set of circumstances, spoilage takes a finite period to occur and equates with the storage life of a product.

A knowledge of the intrinsic and extrinsic parameters should enable you to decide which broad group of organisms is likely to spoil a particular type of food, i.e. whether the food is likely to be spoiled by bacteria, yeasts or moulds. For example, foods that have a high water activity and a pH above 5.0 are likely to be spoiled by bacteria simply because under these conditions bacteria grow the fastest. Foods with pH below 4.2 are likely to be spoiled by yeasts and moulds even when the water activity is high.

2.5.1 Extrinsic Factors

Extrinsic factors relate to the environmental factors that affect the growth rate of micro-organisms. They are as follows:

A. Temperature

Microbes have an optimum temperature as well as minimum and maximum temperatures for growth. Therefore, the environmental temperature determines not only the proliferation rate but also the genera of micro-organisms that will thrive and the extent of microbial activity that occurs. For example, a change of only a few degrees in temperature may favor the growth of entirely different organisms and result in a different type of food spoilage and food poisoning. These characteristics have been responsible for the use of temperature as a method of controlling microbial activity.

The optimal temperature for the proliferation of most micro-organisms is from 15^0 to 40^0C. However, many genera of microbes are capable of growth from 0^0 to 15^0C and other even micro-organisms will grow at subzero temperatures. Still other genera will grow at temperatures up to and exceeding 100^0C.

Microbes classified according to temperature of optimal growth include:

- *Thermophiles* (high-temperature-loving micro-organisms), with growth optima at temperatures above 45^0C (e.g., *Bacillus stearothermophilus, Bacillus coagulans, and Lactobacillus thermophilus*).

- *Mesophiles* (medium-temperature-loving micro-organisms), with growth optima between 20^0 and 45^0C (e.g., most Bactobacilli and Staphylococci).

- *Psychrotrophs* (cold-temperature-tolerant micro-organisms), which tolerate and thrive at temperatures below 20^0C (e.g., *Pseudomonas* and *Acinetobacter)*.

Bacteria, molds and yeasts each have some genera with temperature optima in the range characteristic of thermophiles, mesophiles, and psychrotrophs. Molds and yeasts tend to be less thermophilic than bacteria. As temperature approaches 0^0C, fewer micro-organisms can thrive and their proliferation is slower. As temperature falls below approximately 5^0C, proliferation of spoilage micro-organisms is retarded as the growth of nearly all pathogens ceases.

B. Oxygen Availability

As with temperature, the availability of oxygen determines which micro-organisms will be active. Some micro-organisms have an absolute requirement for oxygen, whereas others grow in total absence of oxygen. Yet other micro-organisms can grow either with or without available oxygen. Micro-organisms that require free oxygen are called aerobic micro-organisms (e.g., *Pseudomonas* spp.) and those that thrive in the absence of oxygen are called anaerobic micro-organisms (e.g., *Clostridium* spp.). Micro-organisms that can grow with or without the presence of free oxygen are called facultative micro-organisms (e.g., *Lactobacillus* spp.).

C. Relative Humidity

This extrinsic factor affects microbial growth and can be affected by temperature. All micro-organisms have high requirements for water to support their growth and activity. A high relative humidity can cause moisture condensation on food, equipment, walls, and ceilings. Condensation causes moist surfaces, which are conducive to microbial growth and spoilage. Also, microbial growth is inhibited by a low relative humidity. Micro-organisms bacteria require the highest relative humidity of the various. Optimal relative humidity for bacteria is 92% or higher, whereas yeasts need 90% or higher and for molds, the value of relative humidity is 85-90%.

2.5.2 Intrinsic Factors

Intrinsic factors that affect the rate of proliferation relate more to the characteristics of the substrates (foodstuff or debris) that support or affect growth of micro-organisms. These major intrinsic factors are:

A. Water Activity (a_w)

Water is required by micro-organisms, and a reduction of water availability constitutes a method of food preservation through reduction of microbial proliferation. It is important to recognize that it is not the total amount of moisture present that determines the limit of microbial growth, but the amount of moisture which is readily available for metabolic activity of microbes. The unit of measurement for water requirement of microorganism is usually expressed as water activity (a_w). Water activity is defined as the vapor pressure of the subject solution divided by the vapor pressure of the pure solvent: $a_w = p/p_0$, where p is the vapor pressure of the solution and p_o is the vapor pressure of pure water. The approximate optimal a_w for the growth of many micro-organisms is 0.99, and most microbes require an a_w higher than 0.91 for growth. The relationship between relative humidity (RH) and a_w is RH = $a_w \times 100$. Therefore an a_w of 0.95 is equivalent to an RH of 95%. Generally, bacteria have the highest water activity requirements of the micro-organisms. Molds normally have the lowest a_w requirements, with yeasts being intermediate. Most spoilage bacteria do not grow at an a_w below 0.91, but molds and yeasts can grow at an a_w of 0.80 or lower. Molds and yeasts are more likely to grow in partially dehydrated surfaces (including food), whereas bacterial growth is retarded.

Approximate Minimum (a_w) Values for Growth

ORGANISMS GROUPS	WATER ACTIVITY
MOST SPOILAGE BACTERIA	0.90
MOST SPOILAGE YEASTS	0.88
MOST SPOILAGE MOLDS	0.80

B. pH

The pH for optimal growth of most micro-organisms is near neutrality (7.0). Yeasts can grow in an acid environment, but grow best in an intermediate acid (4.0-4.5) range. Molds tolerate a wider range of pH (2.0-8.0), although their growth is generally greater with an acid pH. Molds can thrive in a medium that is too acid for either bacteria or yeasts. Bacterial growth is usually favoured by near-neutral pH values. However, acidophilic (acid-loving) bacteria will grow on food or debris down to a pH value of approximately 5.2. Below pH 5.2, microbial growth is dramatically reduced when compared from growth in the normal pH range (Fig. 2.2).

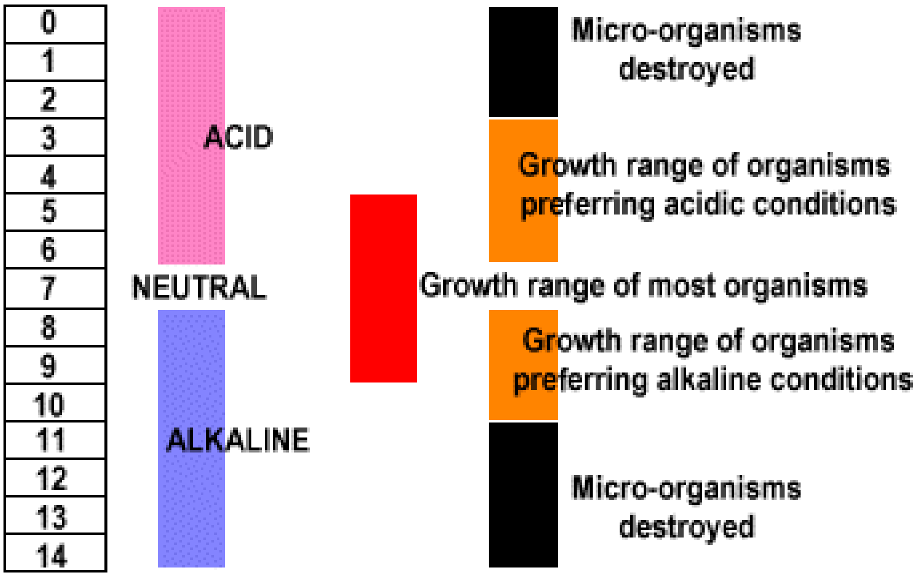

Fig. 2.2: pH and growth of micro-organisms

C. Oxidation – Reduction Potential

The oxidation – reduction (redox) potential is an indication of the oxidizing and reducing power of the substrate. To attain optimal growth, some micro-organisms require reduced conditions while others need oxidized conditions. Thus, the importance of the oxidation-reduction potential is apparent. Aerobic micro-organisms grow more readily under a high oxidation – reduction potential (oxidizing reactivity). A low potential (reducing reactivity) favors the growth of anaerobes. Facultative micro-organisms are capable of growth under either condition. Micro-organisms can alter the oxidation-reduction potential of food to the extent that the activity of other micro-organisms is restricted. For example, anaerobes can decrease the oxidation – reduction potential to such a low level that the growth of aerobes can be inhibited.

D. Nutrient Requirements

In addition to water and oxygen (except for anaerobes), micro-organisms have other nutrient requirements. Most microbes need external sources of nitrogen, energy (i.e., carbohydrates, proteins, or lipids), minerals, and vitamins to support their growth. Nitrogen is normally obtained from amino acids and other nonprotein nitrogen sources; however, some micro-organisms utilize peptides and proteins. Molds are the most effective in the utilization of proteins, complex carbohydrates, and lipids because they contain enzymes capable of hydrolyzing these molecules into less complex components. Many bacteria have a similar capability, but most yeasts require the simple forms of these compounds. Minerals (micronutrients) are needed by all micro-organisms, but requirements for vitamins vary. Molds and some bacteria can synthesize enough B vitamins to fulfill their needs, while other micro-organisms require a ready-made supply.

E. Inhibitory Substances

Microbial proliferation can be affected by the presence or absence of inhibitory substances. Substances or agents that inhibit microbial activity are called bacteriostats, and those which destroy micro-organisms are called bactericides. Some bacteriostatic substances are added during food processing (i.e., nitrites). Most bactericides are utilized as a method of decontaminating foodstuffs or as a sanitizer for cleaned equipment, utensils, and rooms.

2.5.3 Interaction Between Growth Factors

The effects that factors such as temperature, oxygen, pH, and a_w have on microbial activity may be dependent on each other. Micro-organisms generally become more sensitive to oxygen availability, pH, and a_w at temperatures near growth minima or maxima. For example, bacteria may require a higher pH, a_w, and minimum temperature for growth under anaerobic conditions than when aerobic conditions prevail. Micro-organisms that grow at lower temperatures are usually aerobic and generally have a high a_w requirement. Lowering a_w by adding salt or excluding oxygen from foods such as meat which have been held at a refrigerated temperature dramatically reduces the rate of microbial spoilage. Normally, some microbial growth occurs when any one of the factors that control the growth rate is at a limiting level. Yet, if more than one factor becomes limiting, microbial growth is drastically curtailed or completely stopped.

2.6 DETERIORATIVE EFFECTS OF MICRO-ORGANISMS

Food is considered spoiled when it becomes unfit for human consumption. Spoilage is usually equated with the decomposition and putrefaction that result from activity of micro-organisms. Some of the more common physical and chemical changes due to the micro-organisms have been described under:

2.6.1 Physical Changes

The physical changes caused by micro-organisms usually are more apparent than the chemical changes. Microbial spoilage usually results in an obvious change in physical characteristics such as color, body, thickening, odor, and flavor degradation. Food spoilage is normally classified as being either aerobic or anaerobic, depending upon the spoilage conditions, including whether the principal microorganism causing the spoilage were bacteria, molds, or yeasts.

Aerobic spoilage by bacteria and yeasts usually results in slime formation; undesirable odors and flavors (taints); color changes; and rancid, tallowy, or chalky flavors from the breakdown of lipids. Slime formation by certain species of bacteria or yeasts depends upon environmental conditions, especially those of temperature and a_w. Colour changes can be pigment oxidation resulting in a gray, brown, or green color.

Physical deterioration through aerobic spoilage by molds results in sticky surface of many foods. A filamentous appearance frequently referred to as "whiskers" can also occur as a result of physical deterioration. Discoloration from molds can give surface colorations, such as creamy, black, or green. Deterioration from molds can affect appearance of lipids of foods in a way similar to that of bacteria and yeasts and will produce musty odors and alcohol flavors.

Aerobic spoilage of foods from molds is normally limited to the food surface, where oxygen is available. Therefore, molded surfaces of foods such as meats and cheeses can be trimmed off and the remainder is generally acceptable for consumption. This is especially true for aged meats and cheeses. When these surface molds are trimmed, surfaces underneath usually have limited microbial growth. However, if extensive bacterial growth occurs on the surface, penetration inside the food surface usually follows and toxins may be present.

Anaerobic spoilage occurs within the interior of food products or in sealed containers, where oxygen is either absent or present in limited quantities. Spoilage is caused by facultative and anaerobic bacteria and is expressed through souring, putrefaction, or taint. Souring occurs from the accumulation of organic acids during the bacterial enzymatic degradation of complex molecules (carbohydrate). Also, proteolysis without putrefaction may contribute to souring. Souring can be accompanied by the production of various gases. Examples of souring are milk, round sour or ham sour, and bone sour in meat. These meat sours, or taints, are caused by anaerobic bacteria that may originally have been present in lymph nodes or bone joints, or which might have gained entrance along the bones during storage and processing.

2.6.2 Chemical Changes

Through the activity of endogenous hydrolytic enzymes that are present in foodstuffs (and the action of enzymes that micro-organisms produce), proteins, lipids, carbohydrates, and other complex molecules are degraded to smaller and simpler compounds. Initially, the endogenous enzymes are responsible for the degradation of complex molecules. As microbial load and activity increase, degradation subsequently occurs. These enzymes hydrolyze the complex molecules into simpler compounds that are subsequently utilized as nutrient sources for supporting microbial growth and activity. Oxygen availability determines the end products of microbial action. Availability of oxygen permits hydrolysis of proteins into end products such as simple peptides and amino acids. Under anaerobic conditions, proteins may be degraded to a variety of sulfur-containing compounds, which are odorous and generally obnoxious. The end products of non-protein nitrogenous compounds usually include ammonia.

Other chemical changes include action of lipases secreted by micro-organisms which hydrolyze triglycerides and phospholipids into glycerol and fatty acids. Phospholipids are also hydrolyzed into nitrogenous bases and phosphorus. Lipid oxidation is also accelerated by extensive lipolysis.

Most micro-organisms prefer carbohydrates to other compounds as a source of energy. When available, carbohydrates are more readily utilized for energy. Utilization of carbohydrates by micro-organisms results in a variety of end products such as alcohols and organic acids. In many foods such as sausage products and cultured diary products, microbial fermentation of sugar that has been added yields organic acid (e.g., lactic acid) which contribute to their distinct and unique flavors.

2.7 DIFFERENT TYPES OF FOOD SPOILAGE

Food undergoes different types of spoilage depending on its composition as shown in Table 2.2.

Table 2.2: Types of Food Spoilage

Food	**Type of Spoilage**	**Microorganisms Involved**
Bread	Moldy Ropy	*Rhizopus nigricans* *Penicillium* spp *Aspergillus niger* *Bacillus subtilis*
Maple sap and Syrups	Ropy Yeasty Pink Moldy	*Enterobacter aerogenes* *Saccharomyces* spp *Zygosaccharomyces* spp *Micrococcus roseus* *Aspergillus* spp
Fresh fruits and vegetables	Soft rot Grey mold rot Black mold rot	*Rhizopus, Erwinia* *Botrytis* *Aspergillus niger*
Pickles, sauerkraut	Film yeasts, Pink yeasts	*Rhodotorula*
Fresh meat	Putrefaction	*Alcaligenes* *Clostridium* *Proteus vulgaris* *Pseudomonas fluorescens*
Cured meat	Moldy Souring Greening, slime	*Aspergillus* *Rhizopus* *Pencillium* *Pseudomonas* *Micrococcus* *Lactobacillus* *Leuconostoc*
Fish	Discoloration Colourless rot	*Pseudomonas* *Alcaligenes* *Flavobacterium*
Eggs	Green rot Colourless rot Black rot	*Pseudomonas fluorescens* *Pseudomonas alcaligenes* *roteus*
Concentrated Orange juice	Off flavour	*Lactobacillus* *Leuconostoc* *Acetobacter*
Poultry	Slime, odour	*Pseudomonas* *Alcaligenes*

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1) How do bacteria spoil food?

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2) Define water activity.

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3) What is a growth curve?

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4) What is temperature danger zone?

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2.8 COMMON METHODS OF FOOD PRESERVATION

Principles of Food Preservation include the following:

i) Prevention or delay of microbial decomposition.

- By keeping microbes out (asepsis).
- By removal of microbes (e.g. filtration).
- By reducing the rate of microbial growth (e.g. by low temperature, drying, anaerobic conditions and chemical inhibitors).
- By killing microbes (e.g. by heat or radiation).

ii) Prevention or delay of self-decomposition of food

- By inactivation of food enzymes (e.g. blanching).
- By prevention of chemical reactions (e.g. by using antioxidants).

Table 2.3 Methods of food preservation

Operation	Intended effect
Cleaning, washing	Reduces microbial load
Cold storage (below 8^{O}C)	Prevents the growth of most pathogenic bacteria; slows the growth of spoilage microbes
Freezing (below – 10^{O}C)	Prevents growth of all microbes
Pasteurizing (60-80^{O}C)	Kills most non-sporing bacteria, yeast and molds
Blanching (95-110^{O}C)	Kills surface vegetative bacteria, yeast and molds
Canning (above 100^{O}C)	'Commercially sterilizes' food; kills all pathogenic bacteria
Drying	Stops growth of all microbes when a_w <0.60
Salting	Stops growth of most microbes
Syruping (sugars)	Halts growth when a_w < 0.70
Acidifying	Halts growth of most bacteria (effects depend on acid type)

a_w denotes water activity

Food preservation aims at preventing the microbial spoilage of food products and the growth of the food borne pathogens. Thus, the two principal goals of food preservation methods are: (i) increasing the shelf life of the food and (ii) ensuring the safety for human consumption. There are a variety of food preservation methods. Table 2.4 consolidates the methods and details are given here.

2.8.1 Heat

Heat kills micro-organisms by inactivating their proteins and by changing the physical and chemical properties of their proteins. The most common use of heat is in the process of canning. The food product is washed, sorted, and graded and then subjected to steam heat for three to five minutes. This last process called blanching, destroys many enzymes in the food product and prevents further cellular metabolism.

The food is then peeled and cored, and diseased portions are removed. For canning, containers are evacuated and placed in a pressurized steam sterilizer, similar to an autoclave at 121°C. This removes especially *Bacillus* and *Clostridium* spores.

If canning is defective, foods may become contaminated by anaerobic; bacteria which produce gas. These are species of *Clostridium*, and coliform bacteria (a group of Gram-negative nonspore-forming rods which ferment lactose to acid and gas at 32°C in 48 hours).

2.8.2 Low Temperature

Exposure of micro-organisms to low temperatures reduces their rates of growth and reproduction. This principle is used in refrigeration and freezing. Microbes are however not killed. In refrigerators at 5°C, food remains unspoiled. In a freezer at -5°C the crystals formed tear, shred and thereby may kill micro-organisms.

However, some are able to survive. *Salmonella* spp. and Streptococci survive freezing. For these types rapid thawing and cooking is necessary. Deep freezing at -60°C forms smaller crystals. It reduces biochemical activities of microbes.

Blanching of fruits and vegetables, by scalding with hot water or steam prior to deep freezing, inactivate plant enzymes that may produce toughness, change in colour etc. A brief scalding prior to freezing also reduces the number of micro-organisms on the food surface by up to 99% enhances the colour of green vegetables.

2.8.3 Drying or Desiccation

Water from foods is removed in different ways. It may be done by spray dryer which expels a fine mist of liquid such as coffee into a barrel cylinder containing hot air. A heated drum may be used onto which liquids like soup may be poured. Another example is a belt heater that exposes liquids like milk to a steam of hot air that evaporates water and produces dried milk solids.

A common process of freeze drying or lyophilization is used these days. The food is deep frozen, after which the water is drawn off by a vacuum pump in a machine. The dry product is then sealed in foil and is reconstituted with water. This method is very useful for storing, transporting and preserving bacterial cultures.

2.8.4 Osmotic Pressure

The principle of osmosis is applied in the age old traditional method of adding Salt or Sugar to pickles, preserves and jams. Foods are preserved by adding salts and sugars to them. These solutes remove the water out of microbial cells causing them to shrink, thus stopping their metabolism. Jams, jellies, fruit syrups, honey etc. are preserved by using high sugar concentration. Fish, meat, beef and vegetable products are preserved with salt mediated process.

2.8.5 Chemical Preservatives

The most commonly used preservatives are the acids, such as sorbic acid, benzoic acid and propionic acid. These check mainly the growth of yeasts and molds. Sorbic acid is used for preservation of syrups, salads, jellies and some cakes. Benzoic acid is used for beverages, margarine, apple cider etc.

Propionic acid is an ingredient of bread and bakery products. Sulphur dioxide, as gas or liquid is also used for dried fruits, molasses and juice concentrates. Ethylene oxide is used for spices, nuts and dried fruits.

2.8.6 Radiation

Ultra Violet (UV) radiation is used in meat storage facilities which reduce surface contamination, on meat products. Gamma rays are also used for some meat products.

2.8.7 Anaerobiosis

Packaging of food products under anaerobic conditions - anaerobiosis is effective in preventing aerobic spoilage process. Vacuum packing in an airtight container is used to eliminate air.

2.8.8 Controlled Atmosphere

Atmospheres containing 10% CO_2 are used to preserve stored food products such as apples and pears. This checks fungal growth. Ozone can also be added.

2.8.9 Other Methods

These are asepsis i.e. washing utensils that come in contact with food and filtration and centrifugation to remove microbes. Filtration is used for fruit juices and other drinks. Bacteriological filters are used in industries.

2.9 LET US SUM UP

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. Food spoilage is a complex process and

Table 2.4: Preservation Methods and Effect on Micro-organisms

Effect on Microorganisms	Preservation Factor	Method of Achievement
Reduction or inhibition of growth	Low temperature	Chilled and frozen storage
	Low water activity	Drying, curing and conserving
	Restriction of nutrient availability	Compartmentalization in water-in-oil emulsions
	Lowered Oxygen	Vacuum and nitrogen packaging
	Raised carbon dioxide	Modified atmosphere packaging
	Acidification	Addition of acids; fermentation
	Alcoholic fermentation	Brewing; vinification; fortification
	Use of preservatives	Addition of preservatives: inorganic (sulphite, nitrite); organic (propionate, sorbate, benzoate, parabens); bacteriocins (nisin, natamycin)
Inactivation of micro-organisms	Heating	Pasteurization and sterilization
	Irradiating	Ionizing irradiation
	Pressurizing	Application of high hydrostatic pressure

excessive amounts of foods are lost due to microbial spoilage even with modern day preservation techniques. Despite the heterogeneity in raw materials and processing conditions, the micro flora that develops during storage and spoilage of foods can be predicted based on knowledge of the origin of the food, the substrate base and a few central preservation parameters such as temperature, atmosphere, a_w and pH. Based on such knowledge, more detailed sensory, chemical and microbiological analysis can be carried out on the individual products to determine the actual specific spoilage organism.

Generally, foods carry a variety of organisms of which, most are saprophytic. Their presence cannot be avoided since these are mostly from the environment in which the food is prepared or processed. Also, their complete elimination is difficult. However, it is possible to reduce their number or decrease their activities by altering the environmental conditions. A knowledge of the factors that either favour or inhibit their growth is therefore, essential in understanding the principles of food spoilage and preservation.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1) What is food preservation?

....

....

....

2) Food irradiation is ....

3) What are the principles of food preservation?

....

....

....

2.10 KEY WORDS

Additives : Natural and man-made substances added to a food for an intended purpose (such as preservatives and colours) or unintentionally (such as pesticides and lubricants)

Adulteration : Deliberate contamination of foods with materials of low quality.

Aerobic : Requires oxygen

Antimicrobials : Preservatives that protect food by slowing the growth of bacteria, molds and yeasts.

Antioxidants : Preservatives that protect by preventing food molecules from combining with oxygen (air).

Biological Hazard : Danger posed to food safety by the contamination of food with pathogenic micro-organisms or naturally occurring toxins.

Chemical Hazard : Danger posed to food safety by the contamination of food by chemical substances, such as pesticides, detergents, additives, and toxic metals.

Exponential Phase : The period in which the cells of a defined bacterial population are growing and dividing continuously.

Food Acids : Citric acid, tartaric acid, or malic acid used for adjusting the pH value in food.

Food Contact Surface : Any surface of equipment, utensils, containers, wrappings that come in direct contact with food.

Food Preservatives : Prevent spoilage either by slowing the growth of organisms that live on food or by protecting the food from oxygen.

Food Safety : Protecting the food supply from microbial, chemical (i.e. rancidity, browning) and physical (i.e. drying out, infestation) hazards or contamination that may occur during all stages of food production and handling-growing, harvesting, processing, transporting, preparing, distributing and storing. The goal of food safety monitoring is to keep food wholesome.

Food Safety Hazards : Include all microbiological, chemical, and foreign materials that, if consumed, could cause injury or harm.

pH : Measure of the acidity or alkalinity of a solution, defined as the - log10 of the hydrogen ion concentration

Physical Hazard : Particles or fragments of items not supposed to be in foods.

Spoilage Organisms : Micro-organisms naturally found within a food source that cause food spoilage.

Spore : Inactive or dormant state of some rod-shaped bacteria.

Stationary Phase : The stationary phase occurs at the maximum population density, the point at which the maximum number of bacterial cells can exist in an environment. This typically represents the carrying capacity of the environment.

Vegetative Cell : The vegetative cell state is the form in which an organism is able to grow and divide continuously, given favourable conditions. Unlike endospores, vegetative cells are relatively poor at surviving environmental stresses such as high temperature and drying.

2.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points.

1) Spoilage bacteria are micro-organisms that cause food to deteriorate and develop unpleasant odors, tastes, and textures.

2) Foods may also be classified on the basis of stability:

   - Perishable foods such as meat and fish.
   - Semi perishable foods such as potatoes.
   - Stable foods such as cereals, flour and sugar.

   (*Any stable or semistable food becomes perishable food under moist condition*)

3) **Types of spoilage in food:**

   Slime: Food becomes slimy when there are many bacteria that they touch one another farming continuous film of murcilage

   Souring: Foods may go sour when the micro-organisms produce acids, e.g. sour milk.

   Discolouration: Food may become discoloured from microbiological growth. Some molds have colored spores, e.g. black mould on bread, or blue and green mold on citrus fruit. Sometimes meat becomes green due to the growth of micro-organisms

   Gas: Bacteria often produces gas as a by product which affects food, e.g.

   - Meat becomes spongy in texture
   - Packages, cans or vacuum packs will swell

   Odour: Rotten smells develop from the breakdown of components

4) Food spoilage can be caused by a combination of various factors such as light, oxygen, heat, humidity and/or all kinds of micro-organisms.

Check Your Progress Exercise 2

Your answer should include the following points.

1) There are different spoilage bacteria and each reproduces at specific temperatures. Some can grow at the low temperatures in the refrigerator or freezer. Others grow well at room temperature and in the "Danger Zone." Bacteria will grow anywhere if they have access to nutrients and water. Under the right conditions, spoilage bacteria reproduce rapidly and the populations can grow very large. In some cases, they can double their numbers in as little as 20 minutes. The large number of micro-organisms and their waste products cause objectionable changes in odor, taste, and texture hence food spoilage.

2) Qualitatively, water activity / a_w is a measure of unbound, free water in a system, available to support biological and chemical reactions. Water activity affects micro-organisms survival and reproduction, enzymative and chemical reactions. The water activity of a substance is quantitatively equal to the vapor pressure of the substance divided by the vapor pressure of pure water (both measured at the same temperature). Measurements range from 0.00 (dry) to 1.00 (pure water).

3) Growth curve is a graph displaying the behavior of a bacterial population over time.

4) Temperature danger zone are the temperatures between 5° and 60°C (41° and 140°F) at which bacteria grow best.

Check Your Progress Exercise 3

Your answer should include the following points.

1) Food preservation is the process used to slow or stop the progress of spoilage by using heat treatment, sugar, salt, acid or preservatives.

2) Process of exposing food to radiation (rays of energy)

3) Asepsis is keeping out the micro-organisms.

4) Principles of Food Preservation are:

   a) Prevention or delay of microbial decomposition.

      - By keeping microbes out (asepsis);
      - By removal of microbes (e.g. filtration);
      - By reducing the rate of microbial growth (e.g. by low temperature, drying, anaerobic conditions and chemical inhibitors); and
      - By killing microbes (e.g. by heat or radiation).

   b) Prevention or delay of self-decomposition of food

      - By inactivation of food enzymes (e.g. blanching);
      - By prevention of chemical reactions (e.g. by using antioxidants).

2.12 SUGGESTED READING

Banwart, G.J. (1979). *Basic Food Microbiology*, AVI Publishing Co. Inc., Westport, Connecticut.

Frazier, W.C. and Westoff, D.C. (1996). *Food Microbiology*, Tata McGraw Hill Publishing Co. Ltd., New Delhi.

Pelczar, M. Jr.O, Chan, E.C.S. and Kreig, N.R. (1993). *Microbiology*, Tata McGraw Hill Inc., New York.

Garbutt, J. (1998). *Essentials of Food Microbiology,* Arnold International Student's Edition, London.