UNIT 9 MICROBIAL GROWTH IN FOOD AND ITS CONTROL

Structure

9.0 OBJECTIVES

After reading this unit, you will be able to:

- specify role and source of microorganisms in food;
- identify factors affecting growth of microbes in food; and
- outline the factors for controlling growth of microorganisms in food.

9.1 INTRODUCTION

We all know that the primary function of microorganisms in nature is to grow in great numbers at their own. In the first instance, it appears that in their effort to grow rapidly and outclass other species, the microorganisms are trying to ruin our food sources by infecting and destroying plants and animals as well as human beings. However, it is not their primary role. Some of these bacteria are normally present as commensal flora while some cause food spoilage and some cause food poisoning. That's why it is important for us to understand the biological principles of the microbial flora that are associated with animals and plant food sources in their natural habitats (sources) as well as the significance of the microbes. The type of microbial growth in particular type of food depends on many factors. It is necessary to know which organisms are associated with a particular food in its natural state and which organisms are not normal for that particular food. It is, therefore, of value to know the general distribution of bacteria in nature and the general types of organisms normally present under given conditions where meat is processed and handled.

9.2 SOURCES OF MICROORGANISMS IN FOOD

On this planet, the microbes during their growth, carry out many complex reactions that are essential to their perpetuations. To do this, microbes obtain

nutrients from organic matter, some of which constitutes our food items. In this process, microbes contribute immensely to the maintenance of our environment through the nitrogen cycle and cycle of other elements, which has been shown below in the following general reaction:

All organic matter
(carbohydrates, proteins, lipids, etc)
↓
Energy + Inorganic compounds
(nitrates, sulfates, etc.)

Some of the microorganisms are desirable in production of certain foods like fermented food products such as fermented meat sausages, ham, alcohol, beverages etc., whereas, other type of microorganisms bring about spoilage of foods. Some microbes that are also known as 'pathogens' or more popularly as 'germs' may cause food poisoning leading to gastroenteritis in man and animals. Therefore, it becomes relevant to know about the different sources of microorganisms found in foods, since each genus of microorganisms has its own particular nutritional requirements and has adopted itself to a particular environment. These environmental food sources of organisms may be classified in following eight categories:

i) **Soil and Water:** These two environments are placed together because many of the bacteria and fungi that inhabit both share a lot. Soil organisms may enter the atmosphere by the action of wind and later to water bodies when it rains. They also enter water when rainwater flows over soil into bodies ofwater. Aquatic organisms can be deposited over soil through the action of cloud formation and subsequent rainfall. This common cycling results in soil and aquatic organisms being one in the same to a large degree. Some aquatic organisms, however, are unable to persist in soil, especially those that are indigenous to marine waters. *Alteromonas* spp. are aquatic forms that require seawater salinity for growth and would not be expected to persist in soil. The bacterial flora of seawater is essentially Gram-negative, and Gram-positive bacteria exist there essentially only as transients.

ii) **Plants and Plant products:** It may be assumed that many or most soil and water organisms contaminate plants. However, only a relatively small number find the plant environment suitable to their overall well-being. Those that persist on plant products do so by virtue of a capacity to adhere to plant surfaces so that they are not easily washed away and moreover they are able to obtain their nutritional requirements. Notable among these are the lactic acid bacteria and some yeast. Among others that are commonly associated with plants are bacterial plant pathogens in the genera *Corynebacterium, Curtobacterium, Pseudomonas* and *Xanthomonas* and fungal pathogens among several genera of molds.

iii) **Food Utensils:** When vegetables are harvested in containers and utensils, one would expect to find some or all of the surface organisms on the products tocontaminate contact surfaces. As more and more vegetables placed in the same containers, a normalization of the flora would be expected to occur. In the similar way, the cutting block in a meat market along with cutting knives and grinders are contaminated from initially dirty (contaminated) samples, and this process leads to a build-up of organisms, thus ensuring a fairly constant level of contamination of meat-borne organisms.

Check Your Progress 1

1) List the different environmental sources of microbes.

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2) Silage is a known source of ..... (Bacteria) to dairy and meat animals.

3) Some microbes that are also known as 'pathgones' (or) more popularly as "....." may cause food poisoning leading to ..... in human being and animals.

9.3 FACTORS AFFECTING GROWTH OF MICROORGANISMS IN FOOD

The growth of microorganisms in food leads to food spoilage and may cause food poisoning. This microbial growth in food is influenced by many factors. That's why you might have noticed that some foods decay very fast while other types of foods take longer to spoil in the same environment. Similarly, the conditions required to store a particular type of food commodity are different from those needed for other types of foods. Therefore, knowledge about the factors that influence the growth of microorganisms is essential to understand the principles of meat spoilage and preservation. These factors are of two types and have been discussed below.

9.3.1 Intrinsic Parameters

The natural environment inside the plant or animal tissues used as food may either favour or discourage the microbial growth. This internal environment of the food tissues is a result of the combination of several parameters. Since such tissue parameters are an inherent part of a food item, these are known as intrinsic parameters and have been listed below:

- pH
- Water activity (a_w)
- Redox potential
- Nutrient contents
- Antimicrobial constituents
- Biological structures.

i) **pH:** The hydrogen ion concentration of the growth medium has a marked effect on the growth of bacteria. This concentration is normally expressed interms of pH, which is defined as the negative logarithm of the hydrogen ion concentration. The ultimate pH of meat has a significant bearing on the growth of microorganisms present in it.

Substances producing excess of hydrogen ions (H^+) in solution are acidic while excess of hydroxyl ions (OH^-) are termed as basic or alkaline. Every microorganism has its minimal, maximal and optimal requirement of pH for growth. Most bacteria grow optimally at pH 7.0 but not so well below 4.0 or above 9.0. Most bacteria favour a pH near neutrality or slightly on the alkaline side (6.8-7.5). In general, yeast and molds are more acid

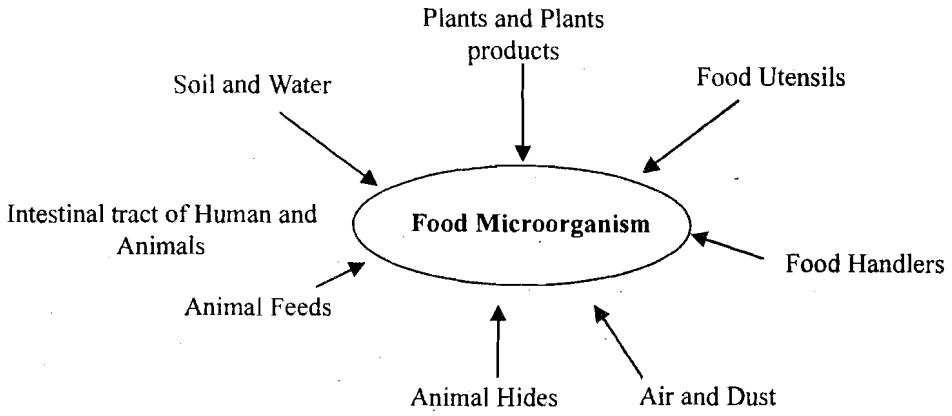

Fig. 9.1: Source of Microorganism

iv) **Intestinal tract of Human and Animals:** This flora becomes a major source of contamination when polluted water is used to wash raw food products. The intestinal flora consists of many organisms and notable among these are disease-causing organisms (pathogens) such as Salmonellae. The organisms excreted from intestine are found in fecal wastes and many of these are disease causing in nature (pathogenic). These include many species of bacteria that are placed in the family- Enterobacteriaceae, and some species of protozoa (such as agents of intestinal amoebiasis) and enteric viruses (such as Hepatitis A and E). The excreted organisms may get their way to food chain with involvement of other host (parasites).

v) **Food Handlers:** The microflora on the hands and outer garments of handlers generally reflects the environment and habits of individuals, and the organisms in question may be those from soil, water, dust, and other environmental sources. Additional important sources are those from the gastrointestinal tract that may enter foods through poor personal hygienic practices.

vi) **Animal Feeds:** This continues to be an important source of many pathogenic organisms such as Salmonellae to poultry and other farm animals. Similarly, the silage is a known source of *Listeria monocytogenes* to dairy and meat animals. The organisms in dry animal feed are spread throughout the animal environment and therefore, may be expected to occur on animal hides.

vii) **Animal Hides:** In the case of cows producing milk, the types of organisms found in raw milk can be a reflection of the flora of the udder, especially when proper cleaning and milking procedures are not followed during milking and the general environment of the shed is not good. The organisms from the udder and hide can contaminate the general environment, milk containers and hands of handlers.

viii) **Air and Dust:** In general, the types of organisms in air and dust would be those that are constantly released to the environment. Accordingly, most of these organisms are also found in food-processing operations and may contaminate the food products. Majority of such flora include the Gram-positive organisms and number of molds (fungi). Besides these usual source of contamination, some organisms also get their way in food chain through mediation of other hosts or vertical transmission (from parents to offspring), for example Salmonella organism in egg may be from laying hen.

tolerant than bacteria. Yeasts and molds grow well in an acid environment of pH 3.5-4.5; molds, whilst favouring acid conditions, usually grow over a wide pH range (3.5-8.0).

ii) **Water activity (a_w):** We know that water is essential for growth and survival of most of the living forms present on this planet. Similarly, the availability of moisture present in foods is an important factor for microbial growth. The water requirement is best expressed in terms of 'available water' or 'water activity (a_w)'. It is defined as the ratio of the vapour pressure of the food to the vapour pressure of pure water at the same temperature. The most rapid growth of microorganisms occurs at a_w in the range of 0.995-0.980, and it is reduced as a_w value goes down. That's why some of the food preservation methods like freezing or drying cause reduction in the a_w of foods.

iii) **Redox potential:** We know that most of the living things need oxygen for their survival. However, the different types of microorganisms require different levels of oxygen for their growth. Accordingly, the microbes that are dependent on free oxygen present in air are termed as 'obligate or strict aerobes'. Few microbes are strictly aerobic in nature but others such as *Pseudomonas* species and the molds growing on the surface of foods are not so strict in their oxygen demand, and therefore, are generally regarded as 'aerobes'. The microbes that grow in the absence of free oxygen *i.e.*, under complete anaerobic conditions are called as 'obligate anaerobes'. This provides us the basis to understand as how the redox potential, *i.e.*, the reducing and oxidizing power of food itself, influences the type of microorganisms growing in food. Foods with high redox potential favours aerobes as well as permit the growth of 'facultative anaerobes' *i.e.*, microbes that grow in the presence or absence of oxygen. On the other hand, foods with low potential favour anaerobic microbes that grow in absence of oxygen. Fresh meat has a low redox potential at the interior. Hence, the meat could support aerobic growth on its surfaces, while anaerobic growth occurs in its interior.

iv) **Nutrient content:** Like human and animal body, the microorganisms present in foods also require certain items as their food in order to grow and function normally. These nutrients include the following items:

- Water
- Source of energy
- Source of nitrogen
- Vitamins and related growth factors
- Minerals.

The importance of water to the growth of microbes has been presented earlier in this chapter. The other four substances listed above are required least by molds followed by yeasts, Gram-negative and Gram-positive bacteria.

As a source of energy, foodborne microorganisms may utilise sugars, alcohols and amino acids. Some of the microbes have ability to first breakdown the complex carbohydrates such as starches and cellulose into simple sugars for their utilization. Only very few microbes that are capable of breaking down the fats (lipolytic microbes) can use fats as sources of energy.

In general, simple compounds such as amino acids will be utilized as the primary nitrogen source by almost all organisms. Some microbes, however, are able to

break down complex high molecular compounds such as proteins into simpler forms like peptides, nucleotides and free amino acids for their utilization.

Microorganisms may require low quantities of B-vitamins, which are present in most of the natural foods. In general, Gram-positive bacteria cannot synthesize more quantities of these compounds, therefore, need supplementation of -B vitamins. On the other hand, Gram-negative bacteria and molds can synthesize these compounds at their own, and therefore, grow freely on foods which are low in B-vitamins such as fruits. This helps to explain why fruits are spoiled frequently by molds rather than bacteria.

In general, the nutritional factors which encourage or support the microbial growth in foods include high moisture, low salt (although Staphylococci can tolerate more salt than other pathogenic bacteria), low acid, low fat, and moderate sugar. The microbial growth is retarded by heat, cold and dehydration, high concentrations of salt, sugar, acid and fat.

v) **Antimicrobial constituents:** Have you ever thought why some foods decay faster in comparison to others? In fact, the stability of some foods against attack by microorganisms is due to the presence of certain naturally occurring substances that have been shown to have antimicrobial activity. Foods may contain a variety of substances, which may affect microbial growth and these may occur naturally, be produced by microbial growth or added artificially. (*Table 9.1*)

vi) **Biological structures:** Let us understand the function of the natural covering of foods. Such coverings are seen in the form of the outer covering of fruits, shell of nuts, hide of animals, and the shell of eggs. These natural barriers provide excellent protection against the entry and subsequent damage by spoilage organisms. The skin covering of fish and meats such as beef and pork prevents the contamination and spoilage of these foods, partly because it tends to dry out faster than freshly cut surfaces.

Table 9.1: Antimicrobial substances

Sl. No.	Type of inhibitory substance	Type of Food	Antimicrobial substance present	Part of food used as source
1.	Naturally occurring (Plant source)	Clove	Eugenol	Essential oil
		Garlic	Allicin	Bulbs
		Cinnamon	Eugenol, Cinnamic-aldehyde	Seed
		Mustard	Allyl isothiocyanate	Seed
2.	Naturally occurring (Animal source)	Egg	Lysozyme and Conalbumin	Egg white (Albumin)
		Milk	Lacteins	Whole milk
3.	By-products of microbial growth leading to reduction in pH	Curd, Shrikhand, Cheddar cheese etc.	Acids-Lactic, Propionic, Butyric	Fermented milk and meat products
4.	Chemicals produced by other microbes i.e., Competitive flora	Preserved foods (Milk, meat)	Bacteriocins: Nisin by *Lactococcus lactis*, Pediocin by *Pediococcus* spp.	Milk and meat products
5.	Chemicals added deliberately to foods during processing	Preserved foods such as pickles, meat products	Synthetic chemicals: Sodium and potassium salts (citrates, pyrophosphate, lactate, nitrites)	Pickle, Ham, Patties etc.

9.3.2 Extrinsic Parameters

The conditions under which foods are stored greatly affect both the food stored and their microorganisms. These storage conditions that make the external environment around the food are referred to as extrinsic factors or parameters and include the following:

- Temperature of storage
- Relative humidity (RH) in the storage environment
- Presence and concentration of gases in the storage environment.

i) **Temperature of storage:** Temperature is the most important factor that affects all the chemical reactions related to microbial growth in foods. Therefore, the temperature of food storage or growth medium has a marked influence on the rate of growth of any microorganism. For any organism, the temperature at which growth is most rapid is known as the 'optimum temperature'. The 'maximum temperature' is the highest temperature at which the organism will grow while the 'minimum temperature' is the lowest temperature at which growth of the organisms can occur, which is usually below the optimum temperature. Based on their optimum temperature for growth, the bacteria have been classified into three groups namely the 'psychrophiles' with optimal temperature of 20-35°C, 'mesophiles' with optimal temperature of 30-35°C, and 'thermophiles' with 45-70°C.

ii) **Relative humidity (RH):** The relative humidity of the storage environment is important both from the standpoint of water activity (a_w) within foods and the growth of microorganisms at the surface. It is important that the food should be stored under conditions of RH that do not allow the food to pick up moisture from the air.

iii) **Presence and concentration of gases in the environment:** When food is stored in an environment (e.g., a packaging film) that contains increased amounts (up to about 10 per cent) of carbon dioxide (CO_2), it is referred to as"controlled atmosphere" or "modified atmosphere" storage. A gas mixture of 10 per cent CO_2, five per cent oxygen (O_2) and 85 per cent nitrogen (N_2) is found to be very effective for the preservation of meat steaks.

Check Your Progress 2

1) What are the extrinsic and intrinsic factors of foods related to microbial growth?

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2) List the types of microorganisms based on their optimum temperature of growth.

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3) Which modified atmosphere is the best for storing meat products in films?

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4) Give the list of microorganisms based on their oxygen requirement for growth in foods?

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9.4 PATTERNS OF MICROBIAL GROWTH IN FOOD

Let us study what course the microorganisms in a food will follow during its growth, and why? The pattern of microbial growth depends on internal environment of a food (intrinsic factors) as well as storage conditions under which it is stored (extrinsic factors) since these may either support or discourage the growth of microorganisms. The growth of microbes in foods or on an artificial growth medium follows a definite course. This pattern of microbial growth in a food or an artificially medium seeded (inoculated) with any microorganism can be studied in the form of a 'microbial growth curve'. The growth curve can be obtained by plotting the count of the bacterial cells against the corresponding storage time (*Fig. 9.2*). Under the conditions favouring growth of microorganisms, a microbial growth curve would show the following four phases:

a) **Lag phase:** Initially, there would not be any appreciable increase in the number of microbes, though there may be an increase in their size. This initial period is the time required for adaptation of microbes to the new environment (food or a medium). During this period of microbial adaptation, adequate quantities of necessary enzymes and metabolic intermediates are build up inside the microbial cells as these would be required for subsequent multiplication. The duration of the lag phase varies with the type of microbial species, size of inoculum, nature of the food or medium, and environmental factors such as temperature (*Fig. 9.2*).

b) **Log (logarithmic) or exponential phase:** Following the lag phase, the cells start dividing by binary fission (one cell is divided into two in each cycle), thereby, doubling their numbers with each successive cycle of cell division. In this manner, the microbes increase in their numbers exponentially or by geometric progression with time, i.e., 1-2-4-8-16-32 and so on. Therefore, if the logarithm of the viable count is plotted against time, a straight line will be obtained (*Fig. 9.2*).

c) **Stationary phase:** After a varying period of exponential growth, cell division stops due to depletion of nutrients and accumulation of toxic products. The number of progeny cells formed is just enough to replace the

number of cells that die. As an equilibrium exists between the dying cells and the newly formed cells, the viable count in this phase remains stationary (*Fig 9.2*).

d) **Phase of decline:** This is the phase when microbial population decreases due to cell death. Besides nutritional exhaustion and toxic accumulation, autolytic enzymes may also cause cell death (*Fig. 9.2*).

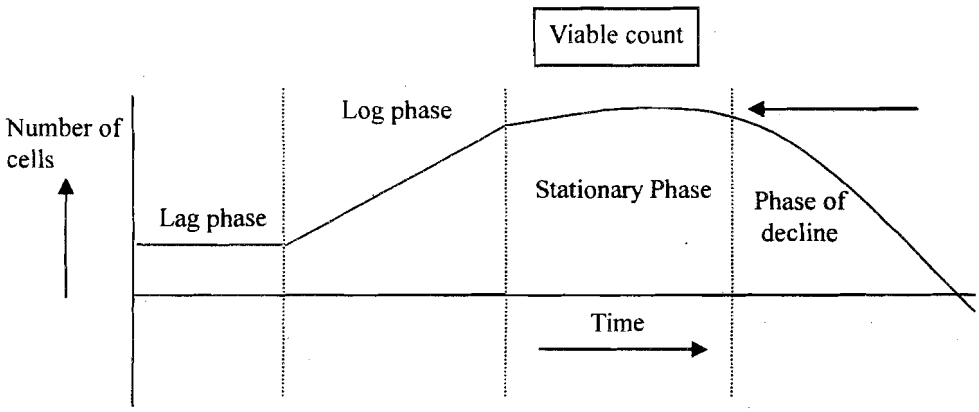

Fig. 9.2: Bacterial growth curve. Showing lag, log, stationary and the decline phases

The principal environmental factors influencing bacterial growth are food, temperature, moisture, oxygen availability, hydrogen ion concentration and the presence of inhibitory substances. The combined effect of these determines the microbial flora.

Check Your Progress 3

1) List the four phases of bacterial growth curve.

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2) What are the causes of death of the cells after stationary phase of their growth?

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9.5 CONTROL OF MICROBIAL GROWTH IN FOOD

The control of microbial growth as used here, means to prevent growth of microorganisms. This control is affected in two basic ways: (A) by killing microorganisms or (B) by inhibiting the growth of microorganisms. Control of growth usually involves the use of physical or chemical agents which either kill or prevent the growth of microorganisms. Agents which kill cells are called 'cidal' agents; agents which inhibit the growth of cells (without killing them)

are referred to as 'static' agents. Therefore, the term 'bactericidal' refers to killing bacteria and 'bacteriostatic' refers to inhibiting the growth of bacterial cells. A 'bactericide' kills bacteria, a 'fungicide' kills fungi, and so on.

9.5.1 Control of Microbial Growth by Physical Agents

To control the growth of microbes in foods, several procedures are used that involve the use of heat, radiation or chemicals, or physical removal of microbial cells.

i) **Application of Heat:** It is the most important and widely used method for sterilization. We should always consider type of heat, time of application and temperature to ensure destruction of all microorganisms. The temperature and time required to kill microbes vary greatly and depend on several factors such as the number of organisms, species, nature of the product being heated, pH, and temperature. Therefore, whenever heat is used to control microbial growth inevitably, both time and temperature are considered. The heat can be applied in two forms: the 'dry heat, such as hot air and the 'moist heat' such as steam. Of these, moist heat is more effective because of better penetration.

Moist heat can be applied by the following methods:

- **Boiling:** The heating of a food item at 100°C for 30 minutes kills everything except some bacterial endospores. Actually, for the purposes of purifying drinking water 100°C for 5 minutes is probably adequate, though there have been some reports that the cysts of protozoa namely *Giardia* can survive this process. Therefore, to sterilize the solution by killing endospores and protozoan cysts, very long or intermittent boiling i.e., boiling three times at 30-minutes intervals followed by periods of cooling, is required.
- **Autoclaving:** It is the application of steam at 121°C for 15 minutes, which can be achieved under pressure (15 pounds per square inch) in a pressure cooker or a especially designed apparatus called 'Autoclave'. It kills all forms of life including bacterial endospores. This process is good for sterilizing almost anything, but heat-labile substances such as rubber and plastic items will be denatured or destroyed.

Dry heat can be applied by following methods:

- **Pasteurization** is the use of mild heat to destroy all the disease-causing microbes (pathogens) and reduce the number of microorganisms responsible for food decay (spoilage flora) in foods. In the case of pasteurization of milk, the time and temperature depend on killing potential pathogens that are transmitted through milk, i.e., staphylococci, streptococci, *Brucella abortus* and *Mycobacterium tuberculosis*. The milk is heated at 63 °C for 30 minutes in Batch method of pasteurization and at 71° C for 15 seconds in HTST (High Temperature Short Time) method.
- **Hot air oven method:** This method is good for sterilizing objects that must remain dry and which are not destroyed at temperature between 121°C and 170°C such as glassware, metal, but not plastic or rubber. In this process, the dry heat is applied in the form of hot air at 160°C for 2 hours or 170°C for 1 hour in a specially designed cabinet called 'Hot air oven'.
- **Incineration:** It attains a temperature higher than 500°C, which burns organisms and physically destroys them. It is used for sterilizing needles,

inoculating wires, glassware, etc. and objects that are not destroyed in the incineration process.

ii) **Low temperature (refrigeration and freezing):** Most organisms grow very littleor not at all at 0°C. Perishable foods are stored at low temperatures to reduce the rate of growth and consequent spoilage (e.g. milk). Low temperatures are only bacteriostatic but not bactericidal.

iii) **Irradiation (microwave, UV, X-ray):** All pathogenic and many spoilage organisms are easily killed by irradiation exposing them to Gamma rays i.e., Gamma irradiation. It usually destroys or distorts nucleic acids (DNA or RNA) of the microbes so that they can not multiply and survive. Ultraviolet light is usually used to sterilize the surfaces of objects and work places.

iv) **Filtration:** This process of sterilization involves the physical removal (exclusion) of all microbial cells from those liquids or gases which would be denatured by heat (e.g. antibiotics, injectable drugs, amino acids, vitamins, etc.).

v) **Drying (removal of water):** Most microorganisms cannot grow at reduced water activity (aw < 0.90). Therefore, removal of water from product by heat, evaporation, freeze-drying and addition of salt or sugar is often used topreserve foods such as fruits, grains, fish, meat etc.

9.5.2 Control of Microbial Growth by Chemical Agents

i) **Chemical and gas:** Toxic chemicals (formaldehyde, glutaraldehyde, ethylene oxide) kill all forms of life in a specialized gas chamber.

ii) **Antimicrobial agents:** These are chemicals that kill or inhibit the growth ofmicroorganisms. Antimicrobial agents include chemical preservatives and antiseptics, as well as drugs used in the treatment of infectious diseases ofplants and animals. Antimicrobial agents may be of natural or synthetic origin, and they may have a static or cidal effect on microorganisms.

Sterilization

It is the complete destruction or elimination of all viable organisms (in or on an object being sterilized). Out of all types of microbial forms, endospores of bacteria are considered the most resistant to heat *i.e.,* thermoduric, therefore, their destruction guarantees sterility.

Sterilization (boiling, autoclaving, hot air oven) kills all microorganisms with heat; commonly employed in canning, bottling, and other sterile packaging procedures. Irradiation destroys microorganisms by using microwave, UV, X-ray. A food or food-processing surface may be rendered sterilized (totally free from microbes or their spores).

Check Your Progress 4

1) Classify the types and methods of heat treatment for control of microbial growth.

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2) List the chemical agents used to control the microbial growth

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3) Whenever heat is used to control microbial growth the factors that are always considerated includes.....and .....

9.6 LET US SUM UP

The factors which encourage the growth of microorganism are high moisture, low salt (although staphylococci can tolerate more salt than other pathogenic bacteria), low acid, low fat, and moderate sugar. Growth is repressed by heat, cold and dehydration, and by high concentrations of salt, sugar, acid and fat.

The various environmental sources responsible for the contamination of the food are: soil and water, food handlers, plants and plants products, animal feeds, food utensils, animal hides, intestinal tract of human and animals, air and dust.

Based on their optimum temperature for growth, the bacteria have been classified into three groups namely, psychrophiles, mesophiles and thermophiles.

The microbial growth in foods depends on the internal environment of a food (intrinsic factors) that includes pH, water availability, redox potential, nutrient contents, antimicrobial constituents and biological structures as well as the storage conditions (extrinsic factors) including temperature of storage, and relative humidity (RH) and concentration of gases in the storage environment.

In the first phase of bacterial growth *i.e.,* lag phase, there is adaptation of microbes to the new environment (food or a medium), thats why the microbes only increase in their size but not in the numbers. In the second phase *i.e.,* log (logarithmic) or exponential phase, the microbes increase in their numbers exponentially or by geometric progression with time. In the third phase *i.e.,* stationary phase, the cell division stops due to depletion of nutrients and accumulation of toxic products, and an equilibrium exists between the number of dying cells and the newly formed cells, therefore, the viable count in this phase remains unchanged i.e., stationary. In the fourth phase *i.e.,* decline phase, the microbial population decreases due to cell death.

Prevention of microbial growth in foods is achieved by two basic ways: (i) by killing microorganisms or (ii) by inhibiting the growth of microorganisms. To control the growth of microbes in foods, several procedures are used that involve the use of heat, radiation or chemicals, or physical removal of microbial cells.

9.7 KEW WORDS

Bactericidal : The agent/process which kills bacteria.

Bacteriostatic : The agent/process which inhibits the growth of bacteria.

Fungicide : The agents which kills fungi.

Pathogens/germs : The agents that cause food poisoning leading to gastroenteritis in man and animals.

Water activity (a_w) : The ratio of the vapour pressure of the food to the vapour pressure of pure water at the same temperature. It is the 'available water' present in food which is actually utilized by the microbes for their growth.

Obligate or strict aerobes: The microbes that are dependent on free oxygen present in air.

Obligate anaerobes : The microbes that grow in the absence of free oxygen i.e., under complete anaerobic conditions

Facultative anaerobes : The microbes that grow in presence or absence of oxygen.

Sterilization : The complete destruction or elimination of all organisms (in or on an object being sterilized).

Pasteurization : Use of mild heat (at a specified temperature and time) to destroy all the disease-causing microbes (pathogens) in foods.

9.8 SOME USEFUL BOOKS

Davies, A. and Board, R. (1998). *The Microbiology of Meat and Poultry*, Blackie Academic & Professional, U.K.

Frazier, W.C. and westhoff, D.C. (1978). *Food Microbiologgy*, 3rd edition, Tata McGrawHill Publishing Company, New Delhi.

Gracy, J.F. and Collins, D.S. (1992). *Meat Hygiene*, 9th edition, ELBS publication, London.

9.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) The environmental sources of microbes are:
   - Soil and water
   - Plant and plant products
   - Food utensils
   - Intestinal tract of human and animals
   - Food handlers
   - Air and dust
   - Animal hides.
2) *Listeria monocytogenes.*
3) "Germs", gastroenteritis.

Check Your Progress 2

1) Extrinsic factors : Temperature of storage, Relative humidity environmental gas.

   Intrinsic factors : pH, water activity, redox potential, nutrient content, antimicrobial constituents and biological structure.

2) Microorganisms are categorized into following three groups based on their optimum temperature of growth:

   Psychrophiles : 20 – 35^{0}C (optimum temperature)

   Mesophiles : 30 - 35^0 C (optimum temperature)

   Thermophiles : 45 - 70^0 C (optimum temperature)

3) A modified atmosphere with 10% CO_2, 5% O_2 and 85% N_2 is the best for storing meat products in films.

4) Depending upon the oxygen requirement for growth, the microorganisms are classified into following three groups: aerobes, obligatory anaerobes and facultative anaerobes.

Check Your Progress 3

1) Four phases of bacterial growth curve are: lag phase, log phase, stationary phase and phase of decline.

2) After stationary phase of the growth, cells die due to nutritional exhaustion, toxic accumulation and autolytic activity of the enzymes.

Check Your Progress 4

1) Types of heat treatment used to control microbial growth:

   Moist heat and dry heat

   Methods of heat treatment used to control microbial growth:

   Boiling, Autoclaving, Hot air oven, Incineration

2) Formaldehyde, Glutaradelyde, ethylene oxide and antimicrobial agents like Ampicillin, Penicillin are the chemical agents to control the microbial growth.

3) Time, Temperature.