UNIT 4 SPOILAGE AND ASSOCIATED CHEMICAL/PHYSICAL CHANGES IN FOOD

Structure

4.0 OBJECTIVES

After reading this unit you should be able to:

- state the meaning of spoilage;
- principle of preservation of food;
- discuss various causes of spoilage;
- describe different types of spoilages; and
- preventive measures which should be taken.

4.1 INTRODUCTION

We all know that food is the basic necessity of all the living entities. Needless to say that such a commodity has to be absolutely safe and of highest possible quality especially free from toxins and spoilage. A food is said to be spoiled if it has been damaged or injured making it unsuitable for human use. "A product is fit as a food if a discriminating consumer, knowing the story of its production and seeing the material itself, will eat it, and conversely, the same product is spoiled when such an examiner refuses it as a food". All of us would agree that a food is spoiled if it is not harvested at proper maturity, is contaminated with dirt, handled by dirty or diseased person, is fertilized with sewage and has objectionable changes due to the activity of microorganisms or action of enzymes of the food. The major causes of spoilage are: the microorganisms or their enzymes, the native enzymes of food, rodents, environmental factors and purely chemical reactions.

It must be admitted that despite of the improvement in the methods of production, handling and processing, the microbiological quality still remains the most important factor. This aspect assumes significance from toxin production, spoilage of fresh and processed products and quality control and as sanitation indicators in a processing unit. Microbial quality is also on the top of the different hazards which are associated with the safety of food for consumption by human beings. Various fruits, vegetables and their products may be spoiled by one or more factors like unsuitable packaging, chemical changes or action of microorganisms, tissue enzymes, insects, rodents or improper methods of processing, under processing, etc. Different spoilage causing agents for various fruit and vegetable products, their prevention and health hazards associated with spoilage are also discussed here.

4.2 PRINCIPLES OF FOOD PRESERVATION

In accomplishing the preservation of food by various methods, three main principles are involved:

I. Delay or prevention of microbial decomposition of food
II. Delay or prevention of self-decomposition of food
III. Prevention of damage caused by insects, rodents, birds, mechanical causes etc.

Various principles and sub-principles of preservation of food are summarized in Table 4.1. First principle of food preservation is based mainly on the following considerations:

- By delaying the microbial decomposition of food
- By preventing the microbial decomposition of food

Most of the methods of food preservation depend not only on the destruction or removal of microorganisms but also on the delay in the initiation of their growth, and hindrance to growth once it has begun. Knowledge of growth curve of microorganisms is very helpful for developing the appropriate technique to delay the microbial decomposition of the food.

Table 4.1: Detailed principles of preservation

I. Delay or prevention of microbial decomposition of food
i) by keeping out microorganisms (asepsis).
ii) by removal of microorganism.
iii) by hindering the growth and activity of microorganisms.
iv) by killing the microorganisms.
II. Delay or prevention of self decomposition of food
i) by inactivation of food enzymes.
ii) by delay or prevention of purely chemical reactions.
III. Prevention of damage to food caused by insects, rodents, birds and mechanical causes

4.3 CLASSIFICATION OF FOODS BASED ON PERISHABILITY

1. *Perishable foods:* The foods which spoil readily unless special preservation methods are used such as meat, fish, most of fruits and vegetables, egg, poultry and milk etc.
2. *Semi-perishable foods:* Semi-perishable foods like waxed potatoes and some varieties of apple, if handled and stored properly, shall remain unspoiled for a fairly long period.
3. *Non-perishable foods:* These foods do not spoil until and unless they are handled carelessly. Such foods are also called as stable foods such as cereals, sugar.

4.4 FACTORS GOVERING SPOILAGE

Since microorganisms are the main spoilage causing factors, major emphasis remains on the factors related to microbial spoilage of the foods. Here bacteria cause most of the problems since these are not killed at ordinary temperatures. The yeasts and molds have low resistance to heat (processing temperatures). The main factors responsible for such spoilage are described here.

4.4.1 Number and Kind of Microorganisms

The initial number of microorganisms present on the food has direct relationship with its spoilage. More the number of microorganisms present, rapid is the spoilage. The effect of initial number of spores on time required to kill them is shown in Table 4.2. The heat resistance of bacteria involved in food poisoning is of major concern from public health view point. Usually, only one type of microorganisms will be there because of the particular environmental conditions involved. However, contamination may increase the number as well as new kinds of microorganims.

Table 4.2: Effect of initial number of spores on time required to kill them

Initial concentration of cells, number/ml	Thermal death time, or time required to kill all spores min. at 121°C
50,000	14
5,000	10
500	9
50	8

In addition to destruction or removal of microorganisms, the delay in the initiation of growth also prevents microbial spoilage. This is done by keeping the microorganisms in lag phase as long as possible. Once the microorganisms enter the log phase, it is very difficult to control them. A typical growth curve of microorganism is shown in Figure 4.1.

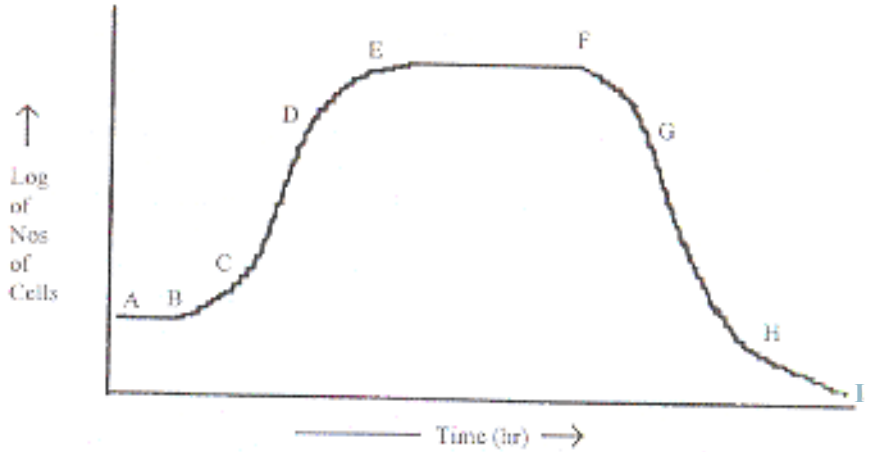

Figure 4.1: Growth curve of microorganism. A to B lag phase, B to C positive acceleration phase, C to D logarithmic phase, D to E negative acceleration phase, E to F stationary phase, F to G accelerated death phase, G to H death phase, H to I survival phase

4.4.2 Suitability of Temperature

Different microorganisms grow at different temperatures. Psychrophiles have affinity for low temperatures (8-10^{o}C), mesophiles grow best at medium temperatures (25-40^{o}C), while thermophiles appear at higher temperatures (50-55^{o}C). A large number of microorganisms grows at mesophilic temperature therefore processed foods are immediately cooled to arrest microbial activity / spoilage of foods. So, storage temperature is very important in relation to microbial growth and hence, the spoilage behaviour of foods.

Different types of microorganisms require different times to kill their cells or spores. The time required to kill all the spores of flat sour bacteria (*Bacillus stearothermophilus)* in relation to temperature is shown in Table 4.3.

Table 4.3: Effect of temperature of heating on the time needed to kill spores of flat sour bacteria

Temperature (^{o}C)	Thermal death time or time to destroy all spores, min.
100	1200
105	600
110	190
115	70
120	19
125	7
130	3
135	1

Source: Adapted from Frazier and Westhoff (1996).

4.4.3 Suitability of food

Different microorganisms prefer different kinds of foods. Some grow best on proteinacious foods, others on starchy or fatty foods. The physical state of the food whether heated, frozen, moistened or dried, also has an important

influence on the spoilage it will undergo. The moisture content also influence the type of microorganisms in the foods since the requirements of moisture for their growth are different. Bacteria, yeast and molds have different moisture requirements in terms of water activity (Figure 4.2).

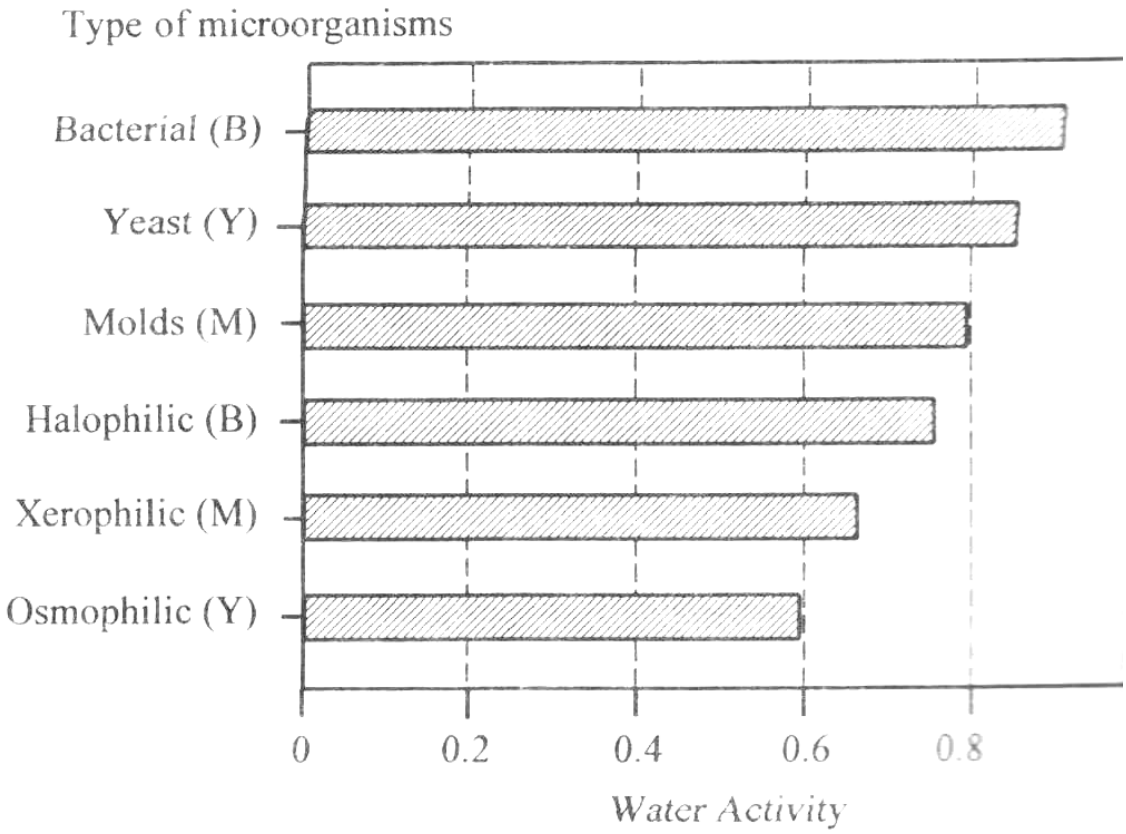

Figure 4.2: Water activity of different microorganisms

4.4.4 pH of Food

The pH of the food influences the kind and growth of microorganisms. The composition of the vegetable, its pH and moisture contents affect their type of spoilage. As a general rule, foods having pH<4.5 (acid foods) do not require heat processing (particularly cooking under pressure), but those with pH > 4.5 (low acid foods) always require processing under pressure.It is because of the reason that thermophilic bacteria may not be killed at normal temperatures as most bacteria thrive best at pH of 4-7.5, while the yeasts and molds require a pH of 2.5-8.0 and 1.5-8.5 for their growth.

4.4.5 Presence of Air

Aerobic or anaerobic microorganisms can be found in the spoiled fruit and vegetable products, depending upon the presence or absence of air (oxygen) in the container or package.

4.5 CHEMICAL AND PHYSICAL CHANGES ASSOCIATED WITH FOOD SPOILAGE

Changes in nitrogeneous organic compounds: Most of the nitrogen in the food present in the form of proteins which are hydrolysed by enzymes to produce amino acids. The anaerobic decomposition of the protein, peptide or amino

acid results in the production of obnoxious odour which is called as putrefaction. When the microorganisms act on amino acid they deaminate or decarboxylate.

E. coli produces glyoxylic acid, acetic acid and ammonia from glycine and from serine it produces pyruvic acid and ammonia. Alanine is degraded into α-keto acid, ammonia and carbon dioxide by *E. coli*; acetic acid, ammonia, and CO_2 by *Psuedomonas*; and propionic acid, acetic acid, ammonia and CO_2 by. *Clostridium nigrificans*. Other nitrogenous compounds like amide, urea, guianidine and creatine, etc. are also decomposed to ammonia, carbon dioxide and other products.

Changes in Carbohydrates: Carbohydrates are preferred by the microorganisms as energy yielding foods. They hydrolyse the polysaccharides to monosaccharides before utilization such as to glucose which is then, oxidized to CO_2 and H_2O. Anaerobically, these undergo decomposition involving one or more types of fermentation.

- Alcoholic fermentation by yeast with ethanol and CO_2 as products.
- Lactic fermentation by homofermentative lactic acid bacteria with lactic acid or by heterofermentative lactic acid bacteria with lactic acid, acetic acid, ethanol, glycerol and CO_2 as chief products.
- Coliform type of fermentation by coliform bacteria with lactic acid, formic acid, ethanol, CO_2, hydrogen and perhaps aceton and butanediol as likely products.
- Propionic acid fermentation by propionoic bacteria producing propionic acid, acetic and succinic acid and CO_2.
- Butyric- butyric isopropyl fermentation by anaerobic bacteria producing butyric acid, acetic acid, CO_2, H_2 and in some cases, butylenes glycol, butanol and 2-propanol.

They are present as salts and are oxidized by the microorganisms to carbonate and cause the food medium to become alkaline. Organic acid aerobically are oxidized to carbon dioxide and water as is done by the film yeast.

Changes in other compounds: Other compounds also undergo changes as detailed here:

- Ethyl alcohol is oxidized to acetic acid.
- Glycoside is hydrolysed to sugars.
- Acetaldehyde is oxidized to acetic acid or reduced to ethanol.
- Protopectin are acted upon by pectinesterase – pectic acid + methanol (water soluble) by hydrolysis of methyl ester. Polygalacturonases destroys the linkage between galactouronic acid unit of pectin or pectic acid to yield smaller chain and ultimately, free D-galacturonic acid, which may be degraded to simple sugar.

Changes in Lipids: Fats present in the media are hydrolysed by lipase into glycerol and fatty acid.Phospholipids may be degraded to their constituents phosphate, glycerol, fatty acid, and nitrogenous base e.g. chlorine.

One or more such changes can be produced in the food undergoing spoilage. The physical and sensory qualities of the food also undergo changes, thus making the product unfit for human consumption.

4.6 MICROBIOLOGY OF FRESH FRUITS, VEGETABLES AND THEIR PRODUCTS

4.6.1 Spoilage of Fruits and Vegetables

In general, fruits and vegetables are bulky, easily damaged mechanically, consist largely of water which is readily lost and above all, are living entities and must be kept so for their longivity. Thus, they are sensitive to their environment viz., temperature, level of oxygen, carbon dioxide and ethylene etc. Spoilage of fresh fruits and vegetables usually occurs during storage and transport and while waiting to be processed into various products. These also get contaminated with spoilage organsims either from each other or when they are laid into the baskets, lugs, boxes etc. during harvesting. Mechanical injuries during transportation further aggravate the deterioration process. The decay of perishables may occur due to the physical factors, action of their own hydrolytic enzymes or microbial contaminants etc as discussed earlier. Since fruits and vegetables after picking are alive for certain time thus, are sensitive to their environment, their rate of metabolism is temperature dependent and they may be damaged by heat or cold or even by levels of different gases in the atmosphere. Oxygen is taken in during respiration and CO_2 heat and water vapours are given-off. As fruits or vegetables are detached from the mother plant, the continuity of the flow of sap is totally disrupted but the respiration and water loss continues leading to exhaustion of food reserve and moisture. The irreparable losses are caused leading to deterioration and eventually spoilage. Spoilage is mainly of 2 types: Abiotic spoilage and Biotic spoilage.

Abiotic spoilage: It is due to the different physical (wilting, caking and melting etc.) and chemical changes in the product (hydrolytic action of enzymes, oxidation of fats, putrefaction of proteins, browning reaction between proteins and sugars). Temperature control is the major factor to provide longevity to the fruits and vegetables.

Biotic spoilage: This includes the microbial action associated with bacteria, yeasts and molds on vegetables and fruits and the normal processes of aging. The species of microorganisms causing food spoilage largely depend upon different factors e.g. kind and variety of fruits/vegetables, environmental condition e.g. storage, temperature, relative humidity of the atmosphere and various gas contents of the atmosphere etc. There are two types of microbial spoilage: (a) Spoilage caused by plant pathogens which attack various parts of the plant used as foods, (b) Spoilage caused by saprophytes. The most common and general type of spoilage in fruits and vegetables are mildew are listed in Table 4.4. Dry rots often lead to darkening and discoloring, and hardening of the surface of vegetables and fruits. In microbial spoilage, the vegetables often develop water soaked musky areas while the fruits generally have brown or white colored patches.

Table 4.4: The chief market diseases of some vegetables and fruits

Item	Market diseases
Onions	Bacterial soft rot, black mold rot, gray mold rot
Garlic	Bacterial soft rot, black mold rot
Green beans	Bacterial soft rot, mold rot, *Rhizopus*
Carrots	Bacterial soft rot, black rot, *Fusarium* rot, gray mold rot, watery soft rot
Beets	Bacterial soft rot, black rot, blue mold rot, *Fusarium* rot
Lemons	*Alternaria* rot, anthracnose, blue mold rots, stem-end rots
Peaches	*Alternaria* (or green mold rot), gray mold rot, black mold rot
Apricots	Blue mold rot, brown rot, *Cladosporium* rot, *Rhizopus* rot
Bananas	*Anthracnose, Fusarium, Gleoporium, Pestalozia*
Grapes	Black mold rot, gray mold rot, *Rhizopus* rot, blue mold rot
Strawberries	Gray mold rot, leather rot (*Phytophthora cactorum*) *Rhizopus* rot
Pears	Black rot, blue mold rot, brown rot, gray mold, *Rhizopus* rot
Potatoes	*Fusarium* tuber rot, bacterial ring rot, bacterial soft rot
Cucumber	*Rhizopus* soft rot, bacterial soft rot, blue mold rot, gray mold rot
Cabbage	Bacterial soft rot, gray mold rot, black rot, watery soft rot
Cauliflower	Bacterial soft rot, gray mold rot, black rot, watery soft rot
Tomatoes	*Alternaria* rot, bacterial canker, bacterial spot, gray mold rot, green mold rot, *Rhizopus* rot

The composition of the fruit/vegetable, its pH and moisture content affect their type of spoilage. Moisture content is usually expressed in terms of water activity ‘aw’. Various microorganisms have different requirements for moisture level (Figure 4.2). Amongst the microorganisms, spoilage can be caused by bacteria, molds/yeasts etc. depending upon the pH of food.

Bacteria: Various groups of bacteria can attack different fruits and vegetables, depending upon their composition such as lactic acid bacteria, acetic acid bacteria, coliform bacteria and sporeforming bacteria. The food can be preserved for longer time by prolonging the lag phase. This can be obtained by avoiding the contamination of the food and turning the environmental conditions e.g. temperature, moisture and pH unfavourable for the growth of contaminants (microorganism). Thus, by lowering the storage temperature of the fruits/vegetables, filling up the storage chamber with the inert gases will definitely lead to longer shelf- life of the vegetables and fruits. pH is another important factor governing the bacterial growth which range between pH 4-8. Growth rate is lowered by a decrease in pH.

Yeasts: Yeasts are widely found in the environment. The yeast growth depends largely upon the nature of fruit product. These are generally fermentative in nature.

Molds: Molds are frequently associated with food products. Some of the molds secrete toxic compounds (mycotoxins) like aflatoxins, patulin etc. Aflatoxin has been detected in dried figs and fig paste while patulin is the most common mycotoxin detected in the processed fruits. The mold *Penicillium expansum* which causes apple rot and some other molds produce patulin. The mycotoxins are deleterious to various animals and presumably the human beings also.

4.7 SPOILAGE OF PROCESSED FRUIT AND VEGETABLE PRODUCTS

The spoilage of processed fruit and vegetable products is also of two types: Abiotic spoilage and Biotic spoilage.

a) **Abiotic spoilage:** It is due to the different physical and chemical changes in the product viz. putrification of proteins, browning reactions between sugars and proteins and the physical changes of colour, caking and melting etc. The temperature and humidity are the main factors responsible for causing this type of spoilage. There is a relationship between moisture content and relative humidity with respect to different causes of spoilage in food products.

b) **Biotic spoilage:** It includes the actions associated with microorganisms, damage caused by insects, rodents etc.

Manifestation of spoilage: The microbial deterioration of a processed food product usually is manifested by alterations in the appearance, texture, colour, odour, flavour or slime formation. The appearance includes colour changes, visible growth of microorganisms, formation of pockets of gas or swelling of cans and microbial growth especially that of molds on the surface of food process (Plate 4.1). As some food products deteriorate, they tend to become soft or mushy. Degradation of foods results in the formation of compounds which have odours and flavours different from those of the fresh food.

Plate 4.1: Different spoiled products from fruits and vegetables. 1) Mold growth on pickle, 2) Mold growth on jam, 3) Mold growth on juice, 4) Mold growth on tomato crush, 5) Puffed can

Spoilage of Canned Fruits and Vegetables

Like other foods, canned fruit and vegetable products are also liable for spoilage for various reasons. Number of microorganisms surviving the heat process, storage temperature, suitability of the canned food to support the growth of the microorganisms, pH of the food, oxygen tension etc. may affect the spoilage of canned foods. Broadly, there are four causes for the spoilage of canned fruit and vegetable products viz., microbiological, physical, chemical and miscellaneous.

Microbiological spoilage: The spoilage caused by the growth of different kinds of microorganisms may be affected by under processing, inadequate cooling, infection resulting from leakage and pre-processing spoilage.

Under processing: Insufficient or improper heat treatment may result in survival of certain microorganisms causing spoilage of food product during subsequent storage. Some lot or a part of the lot may remain under processed or not processed at all (gross under processing) by mistake. As a general rule, only one type of microorganisms (bacteria or yeast or mold) are involved in such spoilage. Most of these are facultative anaerobes unusually heat resistant spore formers. Faulty operation during processing may also cause under processing. This type of spoilage can be avoided by ensuring proper heat transfer, proper retorting and proper stacking of cans in the retort.

Inadequate cooling: Immediately after processing, the cans are cooled using cold water. It gives a sort of shock to the surviving microorganisms and kills them. It also checks overcooking and hence, saves the food from textural disintegration. If cooling is not proper, spoilage can occur. In addition, the cans are cooled down (using fans also) upto 35-38^{o}C only to allow the water to evaporate readily from the can surface. It will check the rusting of cans during storage, which may otherwise lead to some spoilage. It can be avoided by proper cooling after processing.

Infection due to leakage: Post-processing contamination may take place if there is leakage in the cans due to faulty seam, faulty lock seam or pinholes due to corrosion from inside of the can or rusting of can from outside. Here all the types of microorganisms can be present in the food. Lot of oxygen can enter into the can. Contents of such type of cans are not suitable for consumption. To avoid such kinds of spoilage, seam tests should be carried out regularly while in operation, proper hygiene should be maintained and handling should be proper. The cooling water should be chlorinated using 5-7 ppm of chlorine.

Pre-process spoilage: If the raw material is already heavily contaminated many microorganims may survive heat treatment and also the finished product may not be of desirable flavour or quality. It may also be due to faulty procedure during washing (of raw materials, cans and equipment) blanching and filling of cans. Many respiratory gases can develop causing swelling of cans during storage. To avoid such type of spoilage, proper testing of raw materials, proper washing of raw material as well as equipment, chlorination of water and proper sterilization of cans should be practiced.

Thermophillic spore forming anaerobic spoilage: The microbiological spoilage of canned fruits and vegetables can be of different types.

Flat sour: It derives its name from the fact that the ends of the can of food remain flat but the contents become sour. It is mostly found in non-acid foods like canned vegetables by the action of microorganisms (flat sour bacteria). So it cannot be detected without opening of can and culturing the microorganisms. *Bacillus stearothermophilus* and *Bacillus coagulans* are the thermophilic spore-forming bacteria responsible for flat sour type of spoilage. The latter are found in tomato juices. The immediate source of the flat sour bacteria is usually the plant equipment besides sugar, starch or soil.

TA spoilage: It is the short name for spoilage caused by thermophilic anaerobes which do not produce H_2S e.g. *Clostridium thermosaccharolyticum*. It is a sugar-splitting obligate thermophilic, sporeforming anaerobe which produces CO_2 and H_2, causing the swell and even bursting of cans. The spoiled food usually have sour odour and the source of contamination could be the plant equipment, sugar, starch and soil similar to that of flat source.

Sulphide or Sulphur Stinker spoilage: Such spoilage is caused by *Clostridium nigrificans*, mostly found in low acid foods like peas and corn. The spores of this bacterium are considerably less heat resistant and hence, their appearance in canned foods is indicative of gross under processing. H_2S can be detected by its characteristic odour on opening the can and the organism can also be detected in the form of black (FeS) colonies formed on iron sulphite agar at 55^oC.In case of peas, it is difficult to detect any marked discolouration. The source of this organism includes sugar, starch, soil, manure and the plant equipment.

Mesophilic spoilages: Some species of *Bacillus* and *Clostridium*, non-spore forming bacteria and even yeasts or molds may spoil the under-processed canned foods. The spore forming mesophilic thermoduric species of bacteria include *C. pasteurianum, C. butyricum, C. botulinum, C. sporogenes, B. sublitis, B. polymyxa,* etc. The non-spore forming mesophilic bacteria involved in the spoilage of tomato products, pears and some other fruits were found to be *Lactobacillus* and *Leuconostoc*. Other such genera may be *Pseudomonas*,

Micrococcus, *Flavobacterium* etc. which may come from water and leaks in the cans.

Spoilage by yeasts: The yeasts have been found to spoil canned fruits, jams, jellies, fruit juices, etc. underleakage or under-processing conditions. Film yeasts like *Candida, Pichia*, *Hansenula* can grow on acid products like saurkraut and pickles osmophilic yeasts like *Saccharomyces rouxi*, *S. mellis* can spoil dry fruits, concentrated fruit juices and honey etc. Salt tolerant yeasts like *Torulopsis* and *Brettanomyces* can grow in brine solution.

Spoilage by molds: The molds are the common spoilage organisms of home canned foods like jams, jellies, marmalades. The common one are *Aspergillus, Penicillium, Byssochlamys fulva* etc.

Spoilage by physical causes: Some physical deformation of the container can lead to spoilage. Faulty technique in operation, under exhausting, over filling and panelling or buckling of the cans can cause spoilage of processed food products.

Faulty technique in operation: Just after retorting, if the pressure is released at once instead of slow release, distortion of can body can occur. Joints or seams may be distorted resulting in leakage. To avoid such kind of spoilage, the pressure in the retort should be released slowly after retorting and standard iron plates should be used for cans.

Under-exhausting: If the air entrapped in the tissues of canned fruit and vegetables, and the filling medium is not expelled properly, adequate vacuum may not develop which may consequently, impair the quality and appearance of the product.

Over-filling: Over-filling of cans does not allow proper vacuum formation after processing. It may also lead to flipper or springer type of spoilage. The proper filling is essential to avoid this defect.

Panelling or buckling: It occurs in case of big sized cans. If there is very high vacuum inside the can, atmospheric pressure can struck or force the can inwards resulting in leakage type of spoilage. To check such spoilage, proper vacuum should be created in the cans carefully.

Chemical spoilage: It includes reactions among ingredients, reactions between can and ingredients, hydrogen swell etc. Mainly, it is due to H_2S production, presence of oxygen, acids etc. H_2S is formed by the action of SO_2 (added through sugar or by decomposition of proteins) and H_2 formed by fruit acid acting on tin plate. If there is sufficient vacuum, H_2 is absorbed after storage for long time. Low acid foods have more H_2 swells. Therefore, pH of the food has important role in checking such spoilages. If the pH is near 4.0, it is favourable for many chemical reactions. To avoid the spoilage, we can assure proper vacuum (by hot filling) in the can and also adjust safe pH of the food prior to canning. Rusting and corrosion and perforation of tin plates: After cooling the processed cans in water, if some water remain on the surface of cans, rusting can take place. Similarly, the hygroscopic nature of the labels can also add to the rusting. In case of acid foods, there are more chances of corrosion and perforation of tin plates. More the oxygen in the can, more is the corrosion. Corrosion is more at higher than at lower temperatures. To avoid corrosion and perforation of tin plates, proper exhausting should be done and cans should not be cooled below 35^oC in water or fans should be used to

evaporate water from the can body and non- hygroscopic in nature labels should be used and be stored at relatively low temperatures.

Metallic contamination: The tannins of raw materials or spices used react with exposed iron of the tin plate to form ferric tannate, a black product. Similarly, the SO_2 on reacting with H_2 forms H_2S that may further react with iron content of the can to form iron sulphide thus, causing spoilage of the processed food product. Also, on using the equipment made of copper or brass after sometime, in spite of thoroughly cleaning, small traces of copper oxide may remain there, which further form black copper sulphide on reacting with H_2S and discolour the product. To avoid such spoilage, proper exhausting and proper selection of equipment, thorough washing of the raw material as well as equipment.

External Appearance of Can

Flipper: A can with mild positive pressure is called a flipper. It may be an initial stage of swell or hydrogen swell but more frequently, it is due to over-filling or under exhausting, leakage or sealing at low temperature. The can ends remain flat but when the sides of can are struck with some hard structure or if the temperature of the contents is increased, bulging of ends take place.

Springer: A mild swell at one or both ends of a can is called a springer. One end may also remain permanently bulged and other flat. Pressure on the bulged end will bring it to normal but it will go to other end. Generally, the food in such cans remains fit for consumption. The reasons are similar as for flipper can.

Swells: In this case, both ends remain bulged. It may be a soft swell or hard swell. In case of soft swell, the ends are not so hard. On applying some pressure, the ends may go inward (normal) but do not remain normal on the removal of pressure. Obviously, in hard swell, can ends are rigidly hard and there is no effect of pressure except bursting or leakage of the can. The swell occurs due to the production of H_2 (formed by action of acids of food and tin plate), CO_2 or other gases (as a result of decomposition of contents by microorganisms) involving both thermophiles or mesophiles. The food is not fit for consumption and may even contain toxins produced by *Clostridium botulinum*.

Leaker: A very small leak may appear in the can due to faulty seam, faulty lock seam or pinholes resulting from corrosion from inside of the can or rusting of the can from outside.

Breather: Tiny leak in the can may allow air to pass back and forth into the can but not the microorganisms. The inside pressure of the can equals outside pressure. The contents may be spoiled due to rusting of can caused by oxygen in air passing through the tiny leak.

Buckled cans: Sometimes, the vacuum in big sized cans is so high that atmospheric pressure can strike the can body resulting in deformation of can leading to leakage of contents or contamination.

Spoilage of Fruit and Vegetable Juices

Fruit juice/squashes: The fruit juices are more spoiled by yeasts and molds than by bacteria since they have lower pH while vegetable juices are spoiled more by bacteria than yeasts and molds because of very high pH. If

the fruit and vegetable juices are not processed after extraction, they are spoiled because of enzymatic changes and microbial actions. Apple and grape juices are spoiled by bacteria if the temperature of storage goes above 25^{o}C. Molds can grow on the surface of fruit juices if exposed to air. Most fruit juices have sufficient sugar to favour the growth of yeasts. Deficiency of B group vitamins discourages some bacteria. Concentrates of fruit and vegetable juices favour the growth of yeasts and of acid bacteria and sugar tolerant (*Zygosacharomyces)* species because of increased acidity and sugar concentration. Fruit juice concentrates are fermented almost exclusively by *Saccharomyces rouxi*, *S. mellis*, *Torulopsis* and *Hansenula*. Typical fermentation products are ethanol and CO_2. Heat treatment during canning of these concentrates usually kills these microorganisms and freezing prevents the growth of such organisms. In fruit squashes, if presevatives are not added in proper concentration, some yeasts (e.g. *Zygosaccharomyces*) can spoil such products.

Spoilage of canned fruit juices: The acidity is the single most important factor affecting microbial spoilage of fruit juices. Most bacteria have an optimum pH near 6.8 but may grow at pH values ranging from 4-8. Yeasts and molds can grow at pH <2.

In canned foods, a pH of 4.5 is used as a borderline between acid and low acid foods, that is foods not requiring and those requiring respectively, the minimum botulinum cook (12 D). The typical spoilage flora of fruit juices is represented by some Clostridia, *Bacillus*, members of Enterobacteriaceae, lactic acid bacteria, *Acetobacteriaceae*, yeasts and molds. The spoilage is characterised by lowering of pH (0.2-0.4 units), development of very high volumes of hydrogen and CO_2, and strong cheesy (butyric) odour. Three types of Bacilli are usually involved in spoilage of fruit juices i.e. *B.coagulans* (flat sour), *B. macerans* and *B. polymyxa* (both by storage at temperature < 46^{o}C).

The spoilage by enterobacteriaceae is characterised by the production of lactic acid, acetic acid, formic acid, H_2 and CO_2. Lactic acid bacteria causing spoilage of fruit juices include *Lactobacillus, (L. plantarum, L. fermenti) Leuconostoc mesenteroides, Streptococcus viscosum*. Among the yeasts, the most often involved species in juice fermentation belong to *Saccharomyces, Torulopsis, Candida, Pichia, Hansenula* and *Hanseniaspora.*

Molds require O_2 for development and so usually do not grow at the surface of processed fruit products. However, *Byssochlamys fulva* and *Penicillium expansum*, have been found in canned foods and the latter can grow under vacuum also.

Carbonated beverages are usually not spoiled because of inhibitory effect of CO_2 on microorganisms. The acidity (resulting from carbonation and addition of acids) also inhibits microorganisms. Since molds require air, they do not grow on the carbonated beverages.

Spoilage of Jams, Jellies, Marmalades and Preserves

Jams and jellies have usually low water activity (0.75-0.86). In addition, due to added acid, the pH is lowered and sometimes may have preservatives such as benzoic acid. All these factors lower down the risk of spoilage. Also due to heating, spoilage causing organisms (yeasts, molds) are eliminated until the package is opened whereupon recontamination could be expected (Plate 1).

Usually, osmophilic yeasts such as *Torulopsis*, *Xeromyces* and many other have been reported to spoil jams, jellies and preserves.

Spoilage of Frozen Fruits

Many fruits and fruit products are preserved by freezing including cherries, fruit juice concentrates, purees (^{o}B>45) and some sliced fruits. Usually, dry sugar or syrup is added to fruit prior to freezing. The predominant microorganisms are usually yeasts and molds besides lactic acid bacteria (in orange juice concentrate).

Spoilage of Dried Fruits and Vegetables

In dried fruits (apples, apricots, dates, figs, peaches, prunes, resins etc.), a number of microorganisms can be expected. Due to decreased water activity (<0.65 in case of sun dried products), heat treatment during dehydration and fumigation, the microorganisms may be killed or unable to cause spoilage. But, spores of bacteria and molds are likely to be the most numerous. Dried fruits may be spoiled due to the development of rancidity as concentrated flavonoids may undergo oxidation. Dried or partially dried fruits (dates, figs and prunes) are also susceptible to yeast spoilage i.e. *Zygosaccharomyces*.

4.8 PREVENTIVE MEASURES

While the fresh fruits and vegetables are spoiled by biological (microbiological) and non-biological causes, their spoilage is checked by adopting suitable preservative techniques. But the processed products do not normally spoil unless the preservative technique applied is not proper or is not applied properly or the product is stored improperly. There are a few generalized preventive measures which can be adopted to avoid their spoilage.

- It is desirable to keep the initial microbial contamination as low as possible. The commodities should be handled and stored to avoid further contamination and create conditions to check the growth of microorganisms.
- All efforts be made to apply the preservative technique, keeping in view the various steps to avoid spoilage.
- Mechanical disruption of the processed product tissue should be prevented. Equipments used for handling should be clean and free from contamination and contamination from the soil microflora should be avoided. Dipping of fruits and vegetables in solution of chlorine (50-125 ppm) removes the adhering microflora.
- Inhibition of microbial growth can be achieved by storing the food at low temperature or in inert atmosphere packaging.
- While packaging the processed product, it is absolutely essential that the environment of packing should be microbes free or least contaminated and away from stores to minimize the post-processing contamination.
- The chemical and microbiological quality of water is the single most factor which can control the quality of the finished processed product. It should conform to the prescribed standards of microbiological (indicator microorganism) and chemical quality.

- The spoilage of canned products can be minimized especially leakage by regularly checking the equipments used in canning (reformers, flanger, double seamer, retort).
- The quality of raw material is controllable factor which have profound influence on the spoilage behaviour of processed product.

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. Why the food can get spoiled?

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2. List various causes of spoilage of food?

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3. Enumerate various principles used in preserving food?

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4. What are the major causes of spoilage of canned fruits and vegetable?

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5. Can dehydrated fruits and vegetables also get spoiled if so why?

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6. What is meant by acetification, putrefaction, rancidity, fermentation?

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7. What is meant by hard swell, Hydrgen swell and flat sour?

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8. What is meant by water activity?

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9. Can jams be spoiled?

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10. Name a few microorganisms involved in spoilage of juices.

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11. Can the carbonated juices also get spoiled? If so how?

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12. Enumerate various factors responsible for microbial spoilage.

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13. How would you classify the foods based on perishability?

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14. Classify the microorganisms according to their optimum temperature of growth?

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15. Name the bacterium responsible for causing flat sour.

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16. What is the relationship of initial number of microorganism with spoilage?

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17. Enlist five ways the spoilage can be prevented.

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4.9 LET US SUM UP

The foods especially fruits and vegetable are a living commodities and are therefore, liable for spoilage. The nature and kind of spoilage, however, depend upon the type of food and the environment where it is kept or how it is handled and stored. The causes of spoilage include contamination with microorganisms, activity of microorganisms or their enzymes, activity of native enzymes of food, infestation with rodents and influence of various external conditions where the food is stored. Decomposition of food constituents such as proteins, fats and carbohydrates and their interactions result into production of chemicals with different quality and hence, not acceptable as a food. To prevent spoilage, the foods are preserved either by giving low temperature during storage, or heated in appropriate media, irradiated, dehydrated or preserved with chemicals or made into fermented products. If such methods are not properly employed the foods can get spoiled even when they are processed.

4.10 KEY WORDS

Spoiled food : A food is said to be spoiled if it has been damaged or injured making it unsuitable for human use.

Perishable foods : There are the foods which spoil readily unless special preservation methods are used such as meat, fish, most of fruits and vegetables, egg, poultry and milk etc.

Non-perishable or stable foods : These foods do not spoil until and unless they are handled carelessly such as cereals, sugar etc.

Putrefaction : The anaerobic decomposition of the protein, peptide or amino acid resulting in the production of obnoxious odour is called as putrefaction.

Psychrophiles : Those microorganisms which have affinity for low temperatures (8-10^{o}C).

Mesophiles : Are the microorganisms which grow best at medium temperatures (25-40^{o}C).

Thermophiles : These microorganisms appear at higher temperatures (50-55^{o}C).

Under processing : It denotes insufficient or improper heat treatment that may result in survival of certain microorganisms causing spoilage of food product during their subsequent storage.

Water activity (aw) : Moisture content is usually expressed in terms of water activity.

Under-exhausting : If the air entrapped in the tissues of canned fruit and vegetables and the filling medium is not expelled properly, is called under-exhausting.

Panelling or buckling : It occurs in case of big sized cans when there is very high vacuum inside the can, atmospheric pressure can struck or force the can inwards resulting in leakage type of spoilage.

Flipper : A can with mild positive pressure is called a flipper.

Springer : A mild swell at one or both ends of a can is called a springer. One end may also remain permanently bulged and other flat.

Swells : In this case, both ends remain bulged. It may be a soft swell or hard swell.

Leaker : A can with a very small leak due to faulty seam, faulty lock seam or pinholes resulting from corrosion from inside of the can or rusting of the can from outside is called leaker.

Breather : It denotes tiny leak in the can that may allow air to pass back and forth into the can but not the microorganisms. The inside pressure equals outside pressure.

Buckled cans : Sometimes, the vacuum in big sized cans is so high that atmospheric pressure can strike the can body resulting in deformation of can which may further cause leakage of contents or contamination.

4.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

1. Your answer should include the following points:

   A food is a living commodity and respire and undergo various metabolic changes which if unchecked can spoil the food or if it is not harvested at proper maturity, is contaminated with dirt, or the microorganisms.

2. Your answer should include the following points:

   The major causes of spoilage are: the microorganisms or their enzymes, the native enzymes of food, rodents, environmental factors and purely chemical reactions.

3. Your answer should include the following points:

   - Delay or prevention of microbial decomposition of food.
   - Delay or prevention of self decomposition of food.
   - Prevention of damage to food caused by insects, rodents, birds and mechanical causes.

4. Your answer should include the following points:

   - Microbiological spoilage
   - Spoilage by physical causes

5. Your answer should include the following points:

   Dried fruits can have a number of microorganisms but due to decreased water activity, heat treatment during dehydration and fumigation, the microorganisms may be killed so unable to cause spoilage, but, spores of bacteria and molds may survive and cause spoilage.

6. Your answer should include the following points:

   Acetification: It is the process of conversion of ethanolic liquid into acetic acid by the activity of acetic acid bacteria.

   Putrefaction: The anaerobic decomposition of the protein, peptide or amino acid results in the production of obnoxious odour which is called as putrefaction.

   Fermentation: It is the process in which the organic compounds are converted into other organic compounds with generation of energy.

   Rancidity: It implies the oxidation of fatty substances giving specific off-odour.

7. Your answer should include the following points:

   In hard swells, both the ends of can remain bulged and rigid. In case of soft swell, the ends are not so hard. On applying some pressure, the ends may go inward (normal) but do not remain normal on the removal of pressure.

8. Your answer should include the following points:

   Water activity (aw): Moisture content is usually expressed in terms of water activity.

9. Your answer should include the following points:

   Jams and jellies have usually low water activity (0.75-0.86) so have lower risk of spoilage. However, if package is opened chances of recontamination could be expected or if there is leakage the product could be spoiled by osmophilic yeasts such as *Zygosaccharomyces Torulopsis*, *Xeromyces*.

10. Your answer should include the following points:

    Fungi

    Mucor,
    Rhizopus,
    Penicillium,
    Aspergillus,
    Alternaria, Cladosporium,
    Byssochlamys

Bacteria

Clostridium butyricum
B. coagulans (flat sour)
E. coli
Lactobacillus,
Leuconostoc mesenteroides
Streptococcus viscosum

Yeast

Saccharomyces

11. Your answer should include the following points:

    Carbonated beverages are usually not spoiled because of inhibitory effect of CO_2 on microorganisms. The acidity (resulting from carbonation and addition of acids) also inhibits microorganisms. Since molds require air, they do not grow on the carbonated beverages but may develop at the surface of uncarbonated soft drinks which contain air above the liquid surface.

12. Your answer should include the following points:

    Following are some of the factors responsible for spoilage: Number and kind of microorganisms, Suitability of temperature, Suitability of food, pH of food and Presence of air

13. Your answer should include the following points:

    Perishable foods: are the foods which spoil readily unless special preservation methods are used (meat, fish, most of fruits and vegetables, egg, poultry milk).

    Semi-perishable foods: Semi-perishable foods like waxed potatoes and some varieties of apple, if handled and stored properly, shall remain unspoiled for a fairly long period.

    Non-perishable foods: are the foods that do not get spoiled until and unless they are handled carelessly such as cereals, sugar.

14. Your answer should include the following points:

    Psychrophiles: These have affinity for low temperatures (8-10^{o}C).

    Mesophiles: These microorganisms grow best at medium temperatures (25-40^{o}C).

    Thermophiles: These microorganisms appear at higher temperatures (50-55^{o}C).

15. Your answer should include the following points:

    Bacillus coagulans

16. Your answer should include the following points:

    The initial number of microorganisms present on the food has a direct relationship with its spoilage. More the number of microorganisms present, rapid is the spoilage.

17. Your answer should include the following points:

    1) Keep the initial microbial contamination as low as possible and create conditions to check the growth of microorganisms.

    2) All efforts be made to apply the preservative technique.

    3) Mechanical disruption of the processed product tissue should not occur.

    4) Inhibit microbial growth by storing the food at low temperature or in inert atmosphere packaging of dried fruits and vegetable products.

    5) Equipments used for handling should be clean and free from contamination.

4.12 SOME USEFUL BOOKS

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