# Chapter 2
# Microbial Food Spoilage

The microbial food spoilage is one type of food spoilage that is caused by microorganisms. Food spoilage can define as the process in which the quality of the food deteriorates to some extent which is inconsumable for the person to eat. Food spoilage occurs as a result of the microbial attack, enzymatic digestion, chemical degradation, physical injury etc. The microbial food spoilage can be determined physically by the following method.

**Change in appearance:** The appearance of the food changes by the microbial attack, which forms cloudiness and liquid formation in the food.

**Change texture:** Texture changes occur as a result of slime formation due to an accumulation of microbial cells and tissue degradation.

**Color change:** Color changes due to the chlorophyll breakdown and by the growth of mycelia.

**Change in taste in odor:** The taste and odor of the food changes due to the oxidation of nitrogenous compounds, sulphides, organic acids etc.

## Causes of microbial food spoilage

There are two common factors which favor the growth and multiplication of microorganisms, which include storage conditions of the food and chemical properties of the food.

**Storage conditions of the food:** The storage conditions basically involve two environmental factors like temperature, pH and oxygen that favors the microbial growth on food.

### Temperature

Psychrophilic and psychrotrophic microorganisms have the ability to grow at 0°C. Psychrotrophic microorganisms have a maximum temperature for growth above


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20°C and are widespread in natural environments and in foods. The temperature above this refers as "Mesophilic temperature" which is the most favorable for the microbial growth. A mesophile is an organism that grows best in moderate temperature, neither too hot nor too cold, typically between 20 and 45°C. Therefore the warm temperature is optional for microbial growth like mesophilic and thermophilic microorganisms. A thermophile is an organism—a type of extremophile—that thrives at relatively high temperatures, between 41 and 122°C.

## Oxygen

There are aerobic and anaerobic microorganisms which attack the food in storage conditions either in presence or absence of $O_2$. Aerobic storage conditions favor the aerobic bacteria and molds. If there are anaerobic storage conditions then it will favor the growth of anaerobic bacteria like *Clostridium* sp.

## Chemical properties of the food

Chemical properties are another major factor which causes spoilage due to the food's own chemical properties. The chemical properties of the food that influences the microbial growth.

## Chemical composition of the food

In food, certain organic biomolecules like protein, carbohydrates, and fats are present which are necessary for the microbial growth.

- Protein-rich foods

  In protein-rich foods, the microorganisms which attack are "proteolytic microorganisms". The proteolytic enzyme causes the degradation of protein into simpler forms like amino acids, amines etc. The proteolytic microorganisms include gram-negative, spore forming bacteria.

- Carbohydrate-rich foods

  In carbohydrate-rich foods, the microorganisms which attack are "carbohydrate fermenting microorganisms". Carbohydrate fermenting microorganisms causes the degradation of carbohydrate into the fermentative products by producing acids, alcohols and gases. The carbohydrate fermenting microorganisms include yeast, molds and bacteria (*Micrococcus* sp, *streptococcus* sp.etc).

- Fat rich foods

  In fat-rich foods, the microorganisms which attack are "lipolytic microorganisms". Lipolytic microorganisms causes the degradation of fat into simple forms like fatty acids, glycerol etc. The lipolytic microorganisms includes molds and some gram-negative bacteria.

- Acidity of the food

  The pH below 4.5 doesn't allow the subsequent bacterial growth and are affected mostly by yeasts and molds like in citrus fruits and vegetables. The high pH allows bacterial growth occurs mainly in the non-acid foods.

- Moisture and osmotic concentration of food

  In food, 13% of the free water favors microbial growth. High sugar and salt concentration prevent microbial growth. For the growth of molds, the required sugar concentration is 65-70%. For the growth of yeasts and bacteria, the required sugar concentration is 50%.

## Classification of Food

Based on the spoilage, the food can categorize into 3 types.

**Non perishable food:** It has no water content and can be stored for a long time. These are having a long shelf life.

**Semi perishable food:** It has less water content and can be stored for some time. These are having a medium shelf life.

**Perishable food:** It has high water content and can't store for a long period. These are having a short shelf life. The high water or moisture content is a factor which will directly influence the microbial growth, as water promotes the growth of all living beings. Therefore, the food which is susceptible to the spoilage process refers to the perishable food.

### Microorganisms involved in Food spoilage

There are commonly 3 kinds of microorganisms which causes food spoilage are as follows.

**Yeast:** These are the type of fungi which are single-celled and cause "fermentation of food". Yeasts are of two types namely true yeasts and false yeasts. The favorable condition for the yeasts to cause food spoilage are low pH and low moisture. True yeasts convert sugar into alcohol and carbon dioxide. False yeasts grow on the food surface as a dry film.

**Mold:** These are also the type of fungi, which are multicellular and produce a tough visible mass on the food surface refers as mold growth. These are aerobic organisms which require oxygen to grow, slightly acidic conditions, moisture, a temperature of 20-40$^0$C. They affect mostly the bread, cheese, meat etc.

**Bacteria:** These are organisms which cause food spoilage at low moisture, warm environment (5-60$^0$C), neutral acidity and in the presence of oxygen.

## Process of microbial food spoilage

Microbial food spoilage involves the following steps

**Microbes first attack the food:** As the food contain all the nutrients required by the microorganisms, at a favorable temperature, pH, moisture, oxygen etc.

**Food degradation:** Microorganisms not only degrades the food material by utilizing the nutrients available in the food but also decompose the food material.

**Decomposition:** The enzymatic reaction occurs between the food components like protein, lipid, fat, carbohydrates etc. and the microbial enzymes which carry out some chemical changes.

Changes as a result of food decomposition

The changes appear in the form of appearance, texture, color, taste, odor etc as a result of spoilage.

### Spoiled Food

Damages or injuries that make food undesirable for human consumption. Spoilage of food can be the result of

a) insect damage
b) physical injury
c) enzymatic degradation
d) microbial activity

Basic types of food spoilage

- **Appearance**
  - **Microbial Growth**
    - Mycelia or colonies visible on surface
    - Development of cloudiness in liquids
  - **Changes in food color due to heme or chlorophyll breakdown.**
    - Colony pigments, growth of mycelia etc.
- **Textural Changes**
  - Slime formation
  - Tissue softening due to enzymatic degradation
- **Changes in Taste and odor**
  - Development of nitrogenous compounds (Ammonia, amines etc),

sulphides and organic acid

The numbers and types of microorganism in a food are largely determined by

- Environment from which the food was obtained
- Microbiological quality of the food in its raw or unprocessed state (intrinsic factors)
- Handling and processing sanitation
- Effectiveness of packaging, handling and storage conditions in restricting microbial growth (extrinsic factors)

## Fresh Meat

Chemical composition includes 75% water, 18% protein, 3% fat, 1% ash, traces of carbohydrate, vitamins etc.

### 1. Whole meats

The microflora of fresh meat is composed primarily of

1. Gram-negative aerobic rods such as *Pseudomonas*, *Acinetobacter* and *Moraxella*.
2. *Bacillus* and *Clostridia* (Eg:- *C. perfringens*) are also common on all types of meat.

   Although subsurface portions of meat are generally sterile, some parts such as lymph nodes may be heavily contaminated. Mechanic disruption of the tissue during processing can distribute microorganisms from the meat surface throughout the product. Fresh meats are among the most perishable foods. Several genera of molds grow on the surface of meat and can cause spoilage, but can't grow on meat stored below $5^0$C. Usually fresh cut meats in the refrigerator at high humidity undergo bacterial spoilage by gram-negative aerobes like *Pseudomonas*, *Acinetobacter* and *Moraxella* spp. The intrinsic and extrinsic parameters of ground beef favor these bacteria so strongly that they are almost exclusive spoilage agents. Meat spoilage is characterized by the appearance of off odors and slime which are manifest when surface loads exceeds $10^7$ (CFU/$cm^2$).

### 2. Ground Meats

Same microorganisms as whole meats, but always have higher microbial loads. Greater surface area which gives microbes better access to the food and also trap air to favor the growth of gram-negative aerobic bacteria like *Pseudomonas* spp. Every handling or processing (storage utensils, cutting knives, grinders) step can contribute additional contamination to the final product. One heavily contaminated

piece (eg: lymph node) can contaminate an entire lot when they are ground together.

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1. Slime development
2. Greening caused by microbial production of $H_2O_2$ or $H_2S$

$H_2O_2$ production in meat has been associated with several types of lactic acid bacteria (primarily *Lactobacillus*). The oxidant ($H_2O_2$) react with nitrosohemochrome (cured meat color compound) to form a green porphyrin compound. $H_2S$ greening occurs in fresh meats that have been vacuum packaged and stored between 1-5$^0$C. $H_2S$ react with myoglobin to form sulphmyoglobin in meats with a pH above 6.0. $H_2S$ is produced by *Shewanella putrefaciens* and *Pseudomonas* spp. and some *Lactobacilli*. Off odors which result from the release of short chain fatty acids and the production of volatile compounds like acetoin, diacetyl and $H_2S$.

The type of spoilage bacteria that will dominate is influenced by several factors that include

**1. Is the meat product raw or cooked**

Cooked products have a higher pH (>6.0) which may allow growth of gram-negative facultative anaerobic pathogens like *Yersenia enterolitica*. Raw products have a pH of about 5.6 which favors the lactic acid bacteria, especially *Lactobacillus*, *Carnobacterium* and *Leuconostoc*.

**2. Nitrite concentration in meat**

High nitrite concentration favors lactic acid bacteria. Low nitrite levels may allow growth of *Brochothrix thermosphacta* (gram-positive rod, facultative anaerobe, growth at 0-30$^0$C from pH 5.0-9.0, catalase positive). *B. thermosphacta* is an important spoilage bacterium in anaerobically stored meats kept at low temperature, but the bacterium is inhibited by nitrite.

**3. Processed meats (hot dogs, sausage and luncheon meats)**

These products are composed of a variety of blended ingredients, any of which can contribute microorganisms to the food. Yeast and bacteria are the most common causes of spoilage, which is usually manifest in 3 ways.

a) **Slimy spoilage**: - Like other meat products, this occurs on the surface and is caused by the build up of cells of yeasts. *Lactobacilli*, *Enterococci* or *Brochothrix thermosphacta*. Washing the slime off with hot water can

restore the product quality.

b) **Sour spoilage**: - Results from growth of lactic acid bacteria (which originate from contaminated ingredients like milk solids) under the casing. These organisms ferment lactose and other carbohydrates in the product and produce organic acids. Taste is adversely affected but the product is not harmful if eaten.

c) **Greening due to $H_2O_2$ or $H_2S$ production**: - Greening indicates more extensive product breakdown.

Cured meats (bacon, hams) are resistant to spoilage due to the

1. Use of nitrite/nitrate
2. Smoking or brining of hams
3. The high fat content (thus low $a_w$) of bacon

Instead spoilage of these products is often caused by molds from several genera including *Aspergillus, Fusarium, Mucor, Penicillium, Rhizopus and Botrytis*.

Poultry Meat

Poultry meat like meat of other animals are also susceptible for contamination by various sources. Contamination of skin and lining of the body cavity take place during various processing operations. The organisms of great importance in poultry are *Salmonella* spp. and *Campylobacter jejuni*. Several gram-negative Psychrotropic bacteria viz; *Pseudomonas*, *Acinetobacter* and *Flavobacterium* have also been isolated from poultry carcasses. Ground turkey also may carry fecal *Streptococci*. It is important to freeze the poultry fast in order to keep it in good condition for several months. Freezing further reduces the number of microorganisms in the poultry meat provided the temperature is maintained quite low ($-18^0$C or below).

Fish Spoilage

The spoilage in fish is accompanied by the changes in physical characteristics. Change in color, texture, odor, color of eyes, color of gills, softness of muscle, belly bursting are some of the characteristic of spoiled fish. The spoilage of fish is caused by enzymatic, bacterial and chemical action. The following factors contribute to spoilage of fish.

- High moisture content
- High fat content
- High protein content
- Weak muscle tissue
- Ambient temperature

- Unhygienic handling

## Process of Spoilage

Fish is highly nutritive. It is tasty because of its constituents. The main components of fish are water, protein and fat. The spoilage process starts immediately after the death of fish. The process involves three stages.

1. Rigor mortis
2. Autolysis
3. Bacterial invasion and putrefaction

The rigor mortis is a physical effect on the muscle tissue of fish caused by chemical changes following the death. In live fish, its movements are controlled by chemical signals which cause the rhythmic contraction (stiffing) and relaxation of the muscles. This produces swimming action. After the death, the normal circulatory system breaks down and chemical signals leak into the muscle causing them to stiffen. This process is known as Rigor mortis. After the completion of rigor mortis, muscle stiffness gradually decreases accompanied by increase in pH, ending up in softening of muscle. This is followed by breakdown of proteins by enzymes. This process is called as autolysis. Thus autolysis can be described as an internal breakdown of the structure of the protein and fats due to a complex series of reactions by enzymes. Autolysis of protein starts immediately after rigor mortis and creates favorable conditions for the growth of bacteria.

## Action of the Bacteria

The freshly caught fish will be almost free from bacteria but the surface slime, gills and intestine may contain considerable load of bacteria. When the fish is dead, these bacteria start attacking the fish causing spoilage and produce undesirable compounds. The nature and type of bacteria present in a fish depends upon the water from where it is caught and methods used for handling of the fish after its catch. The important changes brought out by the action of the bacteria in fish are

1. Reduction of TMAO (Trimethylamine N-oxide) to TMA (trimethylamine):- Marine fish contains a small percentage of odorless TMAO which is reduced to an offensive smelling TMA by the action of bacteria.
2. Breakdown of amino acids and formation of primary Amines:- The bacterial action of amino acids present in the fish muscle leads to formation of primary amines. Examples are formation of histamine from histidine, arginine from glutamic acid etc. This bacterial action may cause food poisoning in extreme cases.
3. Breakdown of Urea:- The high concentration of urea in the flesh of some fishes are degraded to ammonia by the microorganisms. The formation of

ammonia is accompanied by an offensive odor.

## Chemical action

The most common chemical action which causes spoilage is the oxidative rancidity in the fatty fishes. The levels of peroxide value and free fatty acid content both a measure of oxidative rancidity are considered an index of quality of fat fishes.

## Bacteria causing spoilage

At chilling Temperature: *Pseudomonas*, *Achromobacter*, *Flavobacterium*

At ordinary atmospheric temperature: *Escherichia*, *Serratia*, *Proteus*, *Sarcina* and *Clostridium*

At higher temperature: *Micrococcus* and *Bacillus*

## Discolorations of fish

Yellow to greenish - *Pseudomonas fluorescence, Micrococcus* and others

Red or Pink - *Sarcina*, *Micrococcus, Bacillus*, or by molds and yeast

Chocolate-brown - Asporogenous yeast

## Spoilage of Egg

Breaks or cracks in egg shell taking place due to transportation or mechanical damage may allow microorganisms to enter into the egg yolk and causes spoilage on storage. Eggs on storage may lose moisture and hence lose weight. The white of the egg becomes thinner and more watery on storage. The major changes in the egg take place due to spoilage organisms. In general the spoilage of eggs are caused by bacteria as compared to molds and can be described as green rot due to the growth of *Pseudomonas fluorescens*, colorless rot due to the growth of *Pseudomonas*, *Acinetobacter* and other species, black rots due to *Proteus*, *Pseudomonas*, red rots due to *Serratia* spp. and custard rots due to *Proteus vulgaris* and *Pseudomonas intermedium*. Growth of *Aeromonas* in the egg yolk turns it to black colour and also there is strong putrid odour due to formation of hydrogen sulphide ($H_2S$). Storage of eggs in high humid atmosphere may help in growth of several molds on the surface of the egg shell. Molds causing spoilage of eggs include species of *Penicillium*, *Mucor*, *Alternaria* etc.

## Microbial Spoilage of Cereals

Cereals are important foods which provide bulk of our dietary requirements.

They are also source of carbohydrates which are metabolized by body for energy generation. Besides cereals also provide minerals, proteins and vitamins.

## Cereal grains and Flours

At initial stages, the grains are contaminated by *Pseudomonas*, *Micrococci*, *Lactobacillus* and *Bacillus*. The initial bacterial population may vary from $10^3$ to $10^6$ per gram while mold population may be more than $10^4$ spores per gram.

Due to low moisture content grains and flour usually have long shelf life if these are properly harvested or stored under proper conditions as microbial growth is not supported. If due to any reason they attain moisture, the microbial growth may occur with molds growing at initial stages of moisture while yeasts and bacteria may grow with increasing moisture.

Spoilage of stored grains by molds is attributed to the following factors.

1. Types and number of microorganisms
2. Moisture content of more than 12-13%
3. Storage temperature
4. Physical damage

Most common species of molds are *Aspergillus*, *Rhizopus*, *Muco*r, *Fusarium*. A significant aspect of spoilage of molds is production of mycotoxins, which may pose danger to health. The process of flour making such as washing, milling reduce the microbial content. Moisture content of less than 15% does not allow growth of molds. Most molds and bacteria in flours can grow only above 17% moisture, thus moistening of flours are essential for spoilage by microbes.

## Spoilage of Bread

Bread is a major product prepared using flours. Dough is prepared from flours which undergo fermentation for which desirable microorganisms must grow. If this fermentation exceeds the required limits, it causes souring. Excessive growth of proteolytic bacteria reduces the gas holding capacity which is otherwise required for dough rising. Spoilage of bread is usually of two types viz. moldiness and ropiness.

During bread making, it is baked at very high temperature, thereby there are less chances of survival of microorganisms. Thus the contamination usually occurs when cooling is done as well as during packing, handling and from the environment. The molds which are prevalent are *Rhizopus stolonifer* (bread mold), *Penicillium expansum*, *Aspergillus niger*, *Mucor* and *Geotrichum* also develop.

Ropiness in bread is usually due to bacterial growth and is considered more prevalent in homemade breads. The chief causative organism is *Bacillus subtilis* or *B. licheniformis*. These are spore forming bacteria surviving baking temperatures. Thus

spores can germinate into vegetative cells, once they get suitable conditions as heat treatment activates them. In ropiness, the hydrolysis of bread flour protein (gluten) takes place by proteinases. Starch is also hydrolysed by amylases, which encourage ropiness. The manifestation of ropiness is development of yellow to brown color and soft and sticky surface. It is also accompanied by odor.

Another type of spoilage of bread is chalky bread which is caused by growth of yeast like fungi. *Endomycosis fibuligera* and *Trichosporon variable*. This spoilage is characterized by development of white chalk like spots.

An unusual spoilage of bread is Red or Bloody bread, which is due to the growth of bacteria *Serratia marcescens*. This organisms produces brilliant red color on starchy foods giving blood like appearance. *Neurospora* and *Geotrichum* may also be involved in imparting pigmentation during spoilage of bread.

### Spoilage of cooked Rice

The biggest problem with detecting food spoilage in cooked rice is that there are no signs at all. It might taste, look and smell like it would normally but still be spoiled. The spoilage is caused by *Bacillus cereus*. Only some strains are harmful to humans by causing foodborne illness, while other strains can be beneficial as probiotics for animals. The spoilage of rice is so common that it ever has a own syndrome, "Fried Rice Syndrome", named by Luke Fisher as the bacteria is classically contracted from fried rice dishes that have been sitting at room temperature for hours.

*B. cereus* bacteria are facultative anaerobes and are able to produce protective endospores. These spores can survive if the rice is cooked in temperatures less than $100^0$C. The problem occurs if the rice is improperly refrigerated, since germination and growth generally occur between 10-$50^0$C, though some strains are psychrotrophic. Cooked rice not meant for either immediate consumption or rapid cooking and refrigeration should be kept at temperature above $60^0$C, which causes a problem since everybody knows cooked rice quickly dries out when left on the stove.

Bacterial growth results in production of enterotoxins, one of which is highly resistant to heat and to pH between 2 and 11. Ingestion leads to two types of illness diarrhoeal and emetic (vomiting) syndrome.

### Uncooked Rice

It is usually easy to spot that it is bad. When the rice is not perfectly dry it means moisture found its way into the package and discarding the package seems to be the right thing to do. Funny or "off" order is a sign of spoilage as well.

## Dairy Products

Raw milk flora may include all microorganisms found on the cowhide (which

include soil and fecal bacteria), udder and milking utensils. It can also include gram-negative and gram-positive bacteria, yeasts and molds. When properly handled and stored, the flora of pasteurized milk is primarily gram-positive bacteria.

Psychrotrophic *Pseudomonads* are common in bulk stored raw milk. They produce heat stable enzymes that can reduce milk quality and shelf life. Pasteurization kills most gram-negative (including *Pseudomonads)*, yeasts and molds. Some gram-negative enzymes, thermotolerant gram-positive bacteria and spores survive. Psychrotrophic *Bacillus* spp. are also common in raw milk.

### Pasteurized Fluid Milk

Pasteurized fluid milk is generally spoiled by a variety of bacteria, yeasts and molds. In the past, milk was usually soured by LAB such as *Enterococci*, *Lactococci*, or *Lactobacilli*, which dropped the pH to 4.5 where milk proteins coagulate (curdling). Today milk is more frequently spoiled by aerobic spore formers such as *Bacillus*, whose proteolytic enzymes cause curdling. Molds may grow on the surfaces of spoiled milk, but the product is usually discarded before this occurs.

### Butter

High lipid content and low $a_w$ make it more susceptible to surface mold growth than to bacterial spoilage. Some *Pseudomonads* can be a problem; "surface taint"- putrid smell caused by the production of organic acids from *P. putrefaciens*. Rancidity due to butterfat lipolysis caused by *P. fragi* are common.

### Cottage Cheese

It can be spoiled by yeasts, molds and bacteria. The most common bacterial spoilage is "slimy curd" caused by *Alcaligenes* spp. (gram-negative aerobic rod found in soil, water and intestinal tract of vertebrates). *Penicillium*, *Mucor* and other fungi also grow well on cottage cheese and imparts stale or yeasty flavors.

### Ripened cheese

Low pH, low $a_w$ and high salt inhibit most spoilage microorganisms except surface mold growth. Spores of *C. butyricum*, *C. sporogenes* and others can germinate in cheeses (eg: Swiss) with intrinsic properties that are less inhibitory (eg: lower salt, higher pH). These organisms may metabolize citrate, lactose, pyruvate or lactic acid and produce butyrate or acetate plus $CO_2$ or $H_2$ gas which "blows" the cheese.

## Bakery Goods

These products are characterized by a low $a_w$, which when stored properly

under low humidity, restricts all microorganisms except molds. *Rhizopus stolonifer* is the common bread mold, and other species from this genus spoils baked goods. Refrigerated frozen dough products have more water and can spoiled by Lactic acid bacteria.

## Fermented Foods and Beverages

The low pH or ethanol content of these products does not allow growth of pathogens, but spoilage can occur. Beer and wine (pH 4-5) can be spoiled by yeasts and bacteria. Bacteria involved are primarily lactic acid bacteria like *Lactobacilli* and *Pediococcus* spp; and acetic acid bacteria like *Acetobacter* and *Gluconobacter* spp. Acetic acid bacteria convert ethanol to acetic acid in the presence of oxygen. The anaerobic bacterium *Megasphaera cerevisiae* can also spoil beer by producing isovaleric acid and $H_2S$.

Spoilage in packaged beer is often due to growth of the yeast *Saccharomyces diastaticus*, which grows on dextrins that brewer's yeast can't utilize. *Candida valida* is the most important spoilage yeast in wine. In either case, spoilage by yeasts results in the development of turbidity, off- flavors and odors.

Wines can also be spoiled by lactic acid bacteria which are able to convert malic acid to lactic acid (malo-lactic fermentation). This reduces the acidity of the wine and adversely affect wine flavor.

## Microbial Spoilage of Canned Foods

Canning is one of the important methods of packaging food for long term storage. Normally food is stored in metallic containers along with heat treatment. The heat treatment varies depending upon the type of food. There is always a chance that microorganisms may survive if the heat treatment is not proper thereby leading to spoilage of food. Usually the incidences of food spoilage in cans are low. The spoilage of can could be due to biological or chemical reasons or combination of both. The biological spoilage is primarily due to microbial growth while chemical spoilage is due to hydrogen produced due to reaction of acid in food and iron on can. The degree of swelling can also be increased by high summer temperature and high altitudes.

### Causes of Spoilage in Cans

#### Chemical Spoilage

The chemical spoilage in most cases is due to the production of hydrogen gas produced in the can because of action of acid of food on iron of can. This spoilage is termed as hydrogen swell. Increased storage temperature, increased acidity of food, improper exhaust, presence of soluble sulfur and phosphorous compound are some of the factors responsible for the hydrogen swell.

## Biological Spoilage

The causes of biological spoilage is the microbial activity. In heat treated cans, the growth of microorganisms occur due to leakage of cans and under processing.

Microbial spoilage of canned foods are classified as caused by thermophilic bacteria and mesophilic organisms. Most common spoilage of microbial origin are known as flat sour spoilage, putrefaction and Thermophilic Anaerobic spoilage (TA spoilage).

## Spoilage by thermophilic spore forming bacteria

Spoilage by thermophilic spore forming bacteria is most prevalent in under processed heat treated canned foods. Their spores survive the heat treatment and undergo vegetative cell formation and subsequent growth in canned conditions. Major spoilage by these organisms are

## Flat sour spoilage

This is caused by souring bacteria. One characteristic of this spoilage is that ends of can remain flat during souring. Because of this condition, the detection of spoilage from outside is not possible thereby culturing of contents become necessary to detect the type of organisms. Main organisms involved are *Bacillus*, while it occurs more frequently in low acid foods. *Bacillus* spp. has ability to produce acid without gas formation.

## T A spoilage

This types of spoilage is caused by thermophilic anaerobe not producing hydrogen sulfide. *Clostridium thermosaccharolyticum* is the main organism involved. It produces acid and gas in foods. Spoiled food produces sour or cheesy smell.

## Sulfur stinker spoilage

This type of spoilage occurs in low acid foods and primarily *Desulfotomaculum nigricans* is involved. The spores of these organisms are destroyed at optimal heat treatment, thus presence of this organism usually indicates under processing in terms of heat treatment. It produces $H_2S$ which produce typical odor.

## Spoilage by mesophilic spore formers

*Bacillus* and *Clostridium* are involved in this type of spoilage which is usually indicative of spoilage.

### Spoilage by non-spore formers

The presence of non-spore formers in cans indicate post processing contamination. The organism whose vegetative cells are heat resistant are more readily found. *Enterococcus*, *Streptococcus thermophilus*, *Micrococcus*, *Lactobacillus*, *Leuconostoc*, *Microbacterium* are the more prominent organisms. Presence of these organisms indicates leakage of container. Cooling water is one of the important sources of contamination, thus Coliforms also gain entry into the can through leakage.

### Spoilage by yeasts and fungi

**Yeasts:** Yeasts and their spores are not thermotolerant, thus they are not found in suitably heat treated cans. Their presence indicates under processing or post pasteurization contamination through leakage. Fermentative yeasts are more prominent and they produce $CO_2$, thus causing swelling of cans. Film yeasts too can grow on the surface of the food products.

**Molds:** Among mold, *Aspergillus* and *Penicillium* are the most spoiling organisms. These can grow at high sugar concentration. Acidification is considered method for the prevention of the growth of molds. Some of the molds are resistant to heat. Molds are more common in home canned foods where heating as well as sealing is not under total aseptic conditions.

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