

Food spoilage

- Vegetables form an integral part of diet due to their role in providing various types of vital nutrients such as carbohydrates, minerals, vitamins, roughage etc. Vegetables being a part of fresh produce, contain high moisture which makes them highly perishable foods and hence more prone to spoilage. Microorganisms gain entry into vegetables from various sources. These sources include:
 - Soil
 - Water
 - Diseased plant
 - Harvesting and processing equipments
 - Handlers
 - Packaging and packing material
 - Contact with spoiled vegetables
- The conditions in which vegetables are stored and transported after harvesting also contribute to rate of spoilage. Other than microbial, sources, the spoilage of vegetables can also occur due to the activity of native enzymes.

Food spoilage

- Spoiled Food

1. Damage or injuries that make food undesirable for human consumption.
2. Can be the result of:
 - a. Infection by micro organisms
 - b. Action of enzymatic degradation
 - c. insect , parasites and rodent damage
 - d. Characteristics and storage condition of food
 - e. Physical and mechanical injury

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- **Spoilage organisms:**

- **Yeasts:** target fruits and vegetables due to their low pH
- **Moulds:** can grow even at very low water activity
- **Bacteria:** most bacteria have limited pH, prolytic bacteria can grow even in media with high pH

- **Factors that influence microbial activity:**

- **Water activity:** lower water activity inhibits microbial growth
- **pH:** most microorganisms have limited pH range
- **Nutrient contents:** growth rate faster is nutrients abundant
- **Temperature:** lower temperature retards microbial growth

Molds	pH 1.5-9.0
Yeast	pH 2.0-8.5
Bacteria	pH 6.5-7.5



**NUTRIENT
REQUIREMENT**

Spoilage in vegetables is mainly affected by composition of vegetable. The non acidic foods are thus spoiled by bacterial rot while acidic foods with dry surfaces are more prone to mold spoilage. The product on which organism grows and types of organisms growing largely determine the character of spoilage.

Bacterial Soft Rot Caused by Erwinia carotovora and Pseudomonas such as Pseudomonas marginalis.

Breaks down pectin, giving rise to a soft, mushy consistency, sometimes a bad odour and water soaked appearance. Vegetables affected onions, garlic, beans, carrot, beets, lettuce, spinach, potatoes, cabbage, cauliflower, radishes, tomatoes, cucumbers, watermelons.

Soft rot in tomato caused by *Erwinia carotovora*. Blue mould rot in tomato caused by *Penicillium* spp. *Penicillium*, *Cladosporium*, *Rhizopus*, *Aspergillus* spp. are responsible for various defects in vegetables. Gray mold rot – caused by *Botrytis cinera* in vegetables. Favoured by high humidity and warm temperature

• Stages of spoilage in vegetables:

- Vegetables are a tempting source of nutrients for spoilage organisms due to their near neutral pH and high water activity
- Bacterial spoilage first causes softening of tissues as pectins are degraded and the whole vegetable eventually degenerates into a slimy mass
- Starches and sugars are metabolized next and unpleasant odors and flavors develop along with lactic acid and ethanol

Normal microflora of vegetables

Bacteria	Fungi
Alcaligenes	Alternaria
Bacillus	Aureobasidium
Erwinia	Botrytis
Micrococci	Fusarium
Pseudomonas	Penicillin
Lactic acid bacteria	Rhizopus



The major types of spoilages by pathogens in vegetables

Type of Spoilage	Causative organisms	Symptoms
Bacterial soft rot	<i>Erwinia carotovora</i> <i>Pseudomonas marginalis</i> <i>Clostridium</i>	Water soaked appearance, soft-mushy, bad odor
Alternaria rot	<i>Alternaria tenuis</i>	Greenish brown to black brown spots
Rhizopus soft rot	<i>Rhizopus sp</i>	Cottony mold growth with small black dots
Blue mold rot	<i>Penicillim digitatum</i>	Bluish green color
Downy mildew	<i>Phytophthora, Bremia</i>	White woolly mass
Black mold rot	<i>Aspergillus niger</i>	Brown to black mass, referred as smut
Fusarium rot	<i>Fusarium</i>	
Sliminess or souring	<i>Saprophytic bacteria</i>	
Stem end rots	<i>Diplodia</i> <i>Alternaria</i> <i>Phomopsis</i>	Involve stem ends
Watery soft rot	<i>Sclerotenia sclerotinium</i>	

SOME MICROBIAL DEFECTS OF VEGETABLES

Food	Defect	Organism
Beans 	<ul style="list-style-type: none"> • Anthracnose • Blight 	<ul style="list-style-type: none"> • Colletotrichum • Xanthomonas
Carrots 	<ul style="list-style-type: none"> • Soft rot • Fungal rot • Decay, Wet rot 	<ul style="list-style-type: none"> • Rhizopus stolonifer • Fusarium • Rhizoctonia carotae
Onions 	<ul style="list-style-type: none"> • Neck rot • Rot • Black mold 	<ul style="list-style-type: none"> • Botrytis allii • Pseudomonas cepacia • Aspergillus niger
Potatoes 	<ul style="list-style-type: none"> • Ring rot • Dry rot 	<ul style="list-style-type: none"> • Corynebacterium • Fusarium
Tomatoes 	<ul style="list-style-type: none"> • Ferment • Fungal rot • Bacterial spot • Soft rot 	<ul style="list-style-type: none"> • Candida, Pichia • Aspergillus • Xanthomonas • Byssochlamys fulva

Microbial spoilage

- Major spoilage micro organisms-Bacteria, yeast and storage may infect
- Food after harvesting, during its handling, processing and storage
- But not all Mos cause spoilage eg. **Lactic acid bacteria –in making of cheese**
- **Yeast for production of wine and beer**
- **Acetobacter – for vinegar production**
- **Spoilage organisms are present every where- in soil, air, water and even in raw & processed food materials.**
- **Vegetables are a good substrate for yeasts, moulds or bacteria**
- It is estimated that 20% of all harvested fruits and vegetables for humans are lost to spoilage by these microorganisms.

(I) Bacteria

- These are unicellular MOs do not contain chlorophyll and cell is 1µm length with smaller diameter in different shape e.g. Cocci had spherical, bacilli are cylindrical, spirilla and vibrios had spiral.
- **Bacterial spores more resistant than yeast and moulds spores. Its rapid growth depends on nature of food material, moisture, temperature and air.**
- **Temperature plays major role in their growth, optimum being generally -37 °C**
- **Some bacteria produce spores which can be destroyed by heating at 121 °C for 30-40 min.**
- **It is very sensitive to acids and destroyed in their presence even at the temperature of boiling water.**
- **Fruits are acidic can be easily sterilized at 100 °C and vegetables are non acidic requires a high temperature of 116 °C.**

The important groups of bacteria are

- (i) **bacillus** : rod shaped
- (ii) **Coccus**: spherical
- (iii) **coccobacillus** : oval- shaped
- (iv) **Aerobes** : require atmospheric oxygen for growth, e.g. Acetobacter aceti;
- **Facultative anaerobes** : can grow with or without atm. Oxygen.
- **Obligate anaerobes**: do not grow in atm. Oxygen.
- **Mesophiles** : requires a temperature below 38 °C **for growth.**
- **Obligate thermophiles**: **grows between 38- 82 °C**
- **Facultative thermophiles**: **grow over the whole range of temperatures covered by mesophiles and obligate thermophiles and below.**
- **Psychrotrophs**: grow fairly well at refrigeration temperature and some can even grow slowly at temperature below freezing.

Important food spoilage bacteria

Group	Genus
acetics	Acetobacter and gluconobacter
Lactics	Lactobacillus, Leuconostoc, Pediococcus, Streptococcus
Butyrics	Clostridium
Propionics	Propionibacterium
Proteol Gytics	Bacillus, Pseudomonas, Clostridium, Proteus etc.

Some useful bacteria are great importance in food processing industry. Acetobacter sp. –also called Vinegar bacteria cause significant spoilage in wine industry- necessary for vinegar production



- Lactobacillus sp- known as “lactic acid bacteria”- produces lactic acid from CHO.

It is a facultative thermophilic –grows abundantly at 50-55°C mostly used for distilling and brewing industries.

- Because bacteria grow more rapidly, they usually out-compete fungi for readily available substrates in vegetables. As a result, bacteria are of greater consequence in the spoilage of vegetables with intrinsic properties that support bacterial growth (favourable pH, Eh).
- Mesophiles used for pickling purpose- Lactobacillus plantarum -found in pickles and olives.
- Microflora of vegetables is primarily composed of:
 - 1. G+ bacteria like lactic acid bacteria (e.g. leuconostocs, lactobacilli, streptococci.**
 - 2. These bacteria cause- lactic souring and spoil wines- prevented by sulphur dioxide conc. 0.007 % in wine**
 3. Coryneforms and staphylococci (the latter coming from the hands of employees during processing.
 4. Staphylococci are usually unable to proliferate but cross-contamination can introduce them into other foods where growth conditions are more favourable.

- **Soft rot**
- a. One of the most common types of bacterial spoilage.
- b. caused by *Erwinia carotovora* and sometimes by *Pseudomonas* spp., which grow at 4°C
- Softening can also be caused by endogenous enzymes.
- Flavr Savr story:
 - a. polygalacturonase (PB); hydrolyzes a (1-4) glycosidic bond in pectin which leads to softening.
 - b. Calgene made antisense RNA to tomato pg, constructs soften slower and so can be harvested after they are ripe (better flavor).
 - c. First commercially avail. genetically engineered vegetable.

1. Bacterial soft rot

- Caused by *Erwinia caratovora*, these are fermenters of pectins.
- *Pseudomonas*, *Clostridium*, *Bacillus* sps have also been isolated from these rots.
- It results in a water soaked appearance, a soft mushy consistency and often a bad odor.



Erwinia Caratovora



Erwinia caratovora



- Yeasts, molds and lactic acid bacteria can also spoil fermented vegetables such as **sauerkraut and pickles**, as well as other acid foods like salad dressings and mayonnaise.
- Spoilage in fermented vegetables is often manifest by off odors or changes in the color (chromogenic colony growth) or texture (softening) of the product.
- In mayonnaise or salad dressing, the first signs of spoilage are usually off odors and emulsion separation.

(ii) Yeast

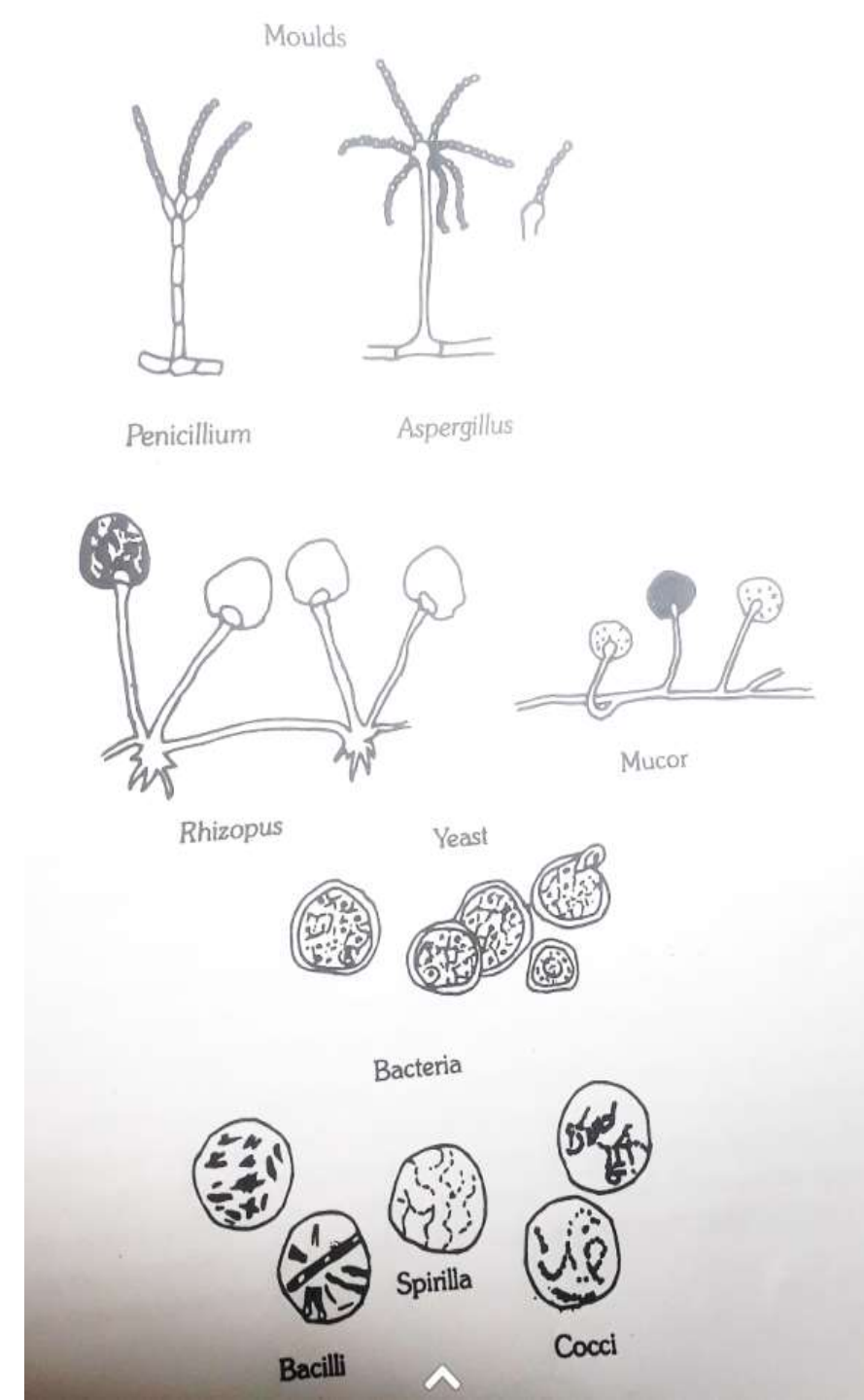
- Yeasts are **microscopic unicellular fungi, which are non-motile round or elliptical.**
- Yeasts are larger than [bacteria](#) in size. It is multiplied by budding and are known as “**true yeasts**”
- It requires less moisture and acidic pH to grow and does not grow in alkaline medium.
- Grow under moderate temperature (**25-30°C**) in sugar solution of **low concentration.**
- **Yeast + Sugar** \longrightarrow **Alcohol + Co₂** \uparrow
- It does not grow in media containing **more than 65 per cent of sugar or 0.5 per cent acetic acid.**
- Heating at 60°C for a few minutes is sufficient to destroy most species of yeasts. Boiling destroys yeast cells and spores effectively.
- It is useful for making bread, beer, wine, vinegar and many other fermented products
- During active [fermentation](#), yeast can **be recognized by formation of bubbles of carbon dioxide gas on the surface of the product.** Some of yeasts which grow on fruits are Saccharomyces, Candida etc. Saccharomyces generally spoils low sugar products whereas Candida is responsible for spoilage of high acid foods, salty foods and butter etc.
- Some yeasts which are like true yeast but do not form spores are known as pseudo-yeasts. This type of yeast is not suitable for [fermentation](#) as they produce off-flavours and cloudiness.

Yeasts causing food spoilage

Yeast	Product spoiled
Saccharomyces	Low sugar products
Candida	High acid foods, salty foods, butter
Brettanomyces	Beers, wines
Pichia	Wines
Zygosaccharomyces (Osmophilic)	Honey, syrups, molasses, wines, soy sauce
Hansenula	Beers
Hanseniospora	Fruit juices
Torulopsis	Milk products, fruit juices, acid foods

(iii) Moulds

- Moulds are multicellular filamentous fungi. They grow on foods with their fuzzy or cottony appearance, sometimes colored.
- Moulds are larger and more complex in structure than [bacteria](#) or yeast
- They are made up of mycelium and spores.
- They grow in a network of hair like fibers called mycelia and send up fruiting bodies that yield spores.
- Some of common moulds are Aspergillus, Penicillium, Rhizopus and Heliminthosporium. Usually a moldy or mildewed food is considered unfit to eat.
- They are strictly **aerobic in nature** and **require less available moisture than yeast** and [bacteria](#) and can grow well at 25-30°C.
- Moulds prefer sugar containing substances like jam, jelly, preserves and other sweet products. They can grow at wide range of pH (2 to 8.5) but majority grow well at acidic pH



- They can grow on many kind of foods especially when temperature, air and humidity are favourable.
- Their growth can be seen only on **the surface of food** .
- Majority of moulds are **sensitive to heat** and are **destroyed at 60°C** when heated for 30 minutes. Boiling quickly destroys both moulds and their spores.
- They not only **consume nutrients present in food thereby lowering the food value** but also produce odd by-products, which spoil the flavour, taste and texture of food hence change the quality contents of the entire product.
- Some moulds produce toxic substances known as mycotoxins. For example *Aspergillus flavus* produces aflatoxins in moist groundnuts .

2. Gray mold rot

- Caused by *Botrytis*.
- It is favored by high humidity and a warm temperature



4. Anthrachose

- Usually caused by *Collectotrichum lindemuthianum*, *Collectotrichum coccodes*, defect is spotting of leaves and fruits or seed pods.

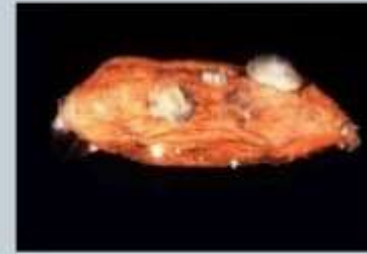


. Rhizopus soft rot

It is caused by sps of *Rhizopus* Ex: *Rhizopus stolonifer*.

This rot is often soft and mushy.

The cottony growth of the mold with small, black dots of sporangia often covers masses of the foods.



5. Alternaria Rot

- Caused by *Alternaria tenuis*.
- Areas become greenish brown early in the growth of the mold and later turn to brown or black spots.



Two basic principals followed in preventing spoilage

- 1. Principal is to destroy MOs in the food and prevent external microbial contaminations.
- Its applies for frozen food.
- It is basis to canning technique.
- 2. It involves altering the environment in order to prevent or retard microbial activity.
- water removal from the growth environment for instance can prevent the microbial decay.
- Applicable for pickled and fermented foods.
- Auto microbial agents – SO₂, benzoic acid, benzoate, hydroxy benzoic acid, sorbic acid, propionic acid, sodium diacetate, Vitamin K5 and antioxidants-Ascorbic acid, ascorbyl palmate, erythorbic acid can used for long term preservation of fruits and vegetables.

Spoilage due to Enzymatic Activity

- Enzymes **are complex chemical substances**, which are present in all living organisms and tissues, which control essential metabolic processes.
- **Different biochemical reactions in foods and plants tissues are catalysed** by enzymes.
- Enzymatic spoilage is the greatest cause of food deterioration.
- **They are responsible for certain undesirable or desirable changes in fruits, vegetables and other foods. Examples involving endogenous enzymes include:**
 - ❖ the post-harvest senescence and spoilage of fruit and vegetables;
 - ❖ **oxidation of phenols** in plant tissues to **orthoquinones** by **phenolases, peroxidases and polyphenol oxidases** (PPO). These orthoquinones rapidly polymerize to form brown pigments known as melanin leading to enzymic browning;
 - ❖ sugar – starch conversion in plant tissues by amylases;
 - ❖ post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).
 - ❖ If enzymatic reactions are uncontrolled, the off-odours, and off-colours may develop in foods.

Factors Affecting Enzymatic Activity

- Factors responsible for controlling enzymatic activities are **temperature, water activity, pH and chemicals which can inhibit or enhance enzyme activity.**
- Enzymes can act **between 0°C and 60°C** but **37°C is optimum temperature.**
- **Enzymes can be permanently inactivated by heat.**
- It has been seen that for **each 10°C rise in temperature, the activity of microorganisms and enzymes increases by at least twice, in the range 0-60°C.**
- **Above this, heat quickly destroys enzymes and stops living cells from working.**
- All enzymes are inactivated at 80°C.
- Decreased temperatures therefore work by slowing down these changes.

Spoilage Due to Insects, Pests and Rodents

- The main categories of foods subject to insects and pest attack are fruits, vegetables, grains and their processed products.
- Warm humid environment promote insect growth, **although most insects will not breed if the temperature exceeds above 35°C or falls below 10°C**. Many insects cannot reproduce satisfactorily unless the moisture content of their food is greater **than 11 per cent**.
- The presence of **insects and pests and their excreta in foods may render consumable loss in the nutritional quality, production of off-flavours and acceleration of decay processes** due to creation of higher temperatures and moisture levels and release of enzymes.
- **The products of insect and pests activities such as webbing, clumped-together food particles and holes can also reduce the food values.**
- **Rats and mice carry disease-producing microorganisms on their feet and/or in their feces and urine and contaminate the food by their presence.**

Spoilage Due to Chemical Reactions

- Chemical reactions take place in the presence of atmospheric oxygen and sunlight.
- **Two major chemical changes**, which occur during the processing and storage of fruits and vegetables, are **lipid oxidation and non-enzymatic browning which deteriorate sensory quality, colour and flavour**.
- Lipid oxidation is influenced by **light, oxygen, high temperature and the presence of iron and copper, and water activity**.
- Control of these factors can significantly **reduce the extent of lipid oxidation or rancidity in foods**.
- **Non-enzymatic browning** is one of the major causes of deterioration which takes place during **frying, cooking, storage of dried and concentrated foods through Maillard, caramelization and ascorbic acid oxidation**.
- **Maillard reaction** occurs due to reactions between reducing sugars and amino acids in the presence of heat and results in formation of black brown insoluble pigments.
- **Caramelization** of sugars occurs in presence of high heat and low moisture content in the food. Oxidation of fatty acids to other chemicals like aldehydes, ketones, alcohols and esters also results in off-flavours.

Spoilage Due to Physical Factors

- Physical factors such as **temperature, moisture and pressure** can also cause **food spoilage**.
- **Physico-chemical reactions** are caused by **freezing**, burning, drying and bruising of fruits and vegetables during storage, handling and transportation, which result in food deteriorations.
- Food processing or storage causes some deterioration in colour of fruits and vegetables due to the **degradation of the chlorophyll resulting dull olive-brown colour**.
- Dehydrated green peas and beans packed in glass containers undergo **photo-oxidation and loss of desirable colour occurs**.
- Freezer induced damage observed in frozen foods affects its quality .
- **Anthocyanins, the pigment in fresh and processed foods, form complexes with metals resulting in the change in colour**. E.g. Red sour cherries react with tin and form undesirable purple complex.
- **Carotenoid, another colour pigment, degrades by oxidation in the presence oxygen, light and heat**.

Effects of Spoilage on Nutritional Quality

Effect of spoilage on nutrient degradation cannot be generalized because of the diverse nature of the various nutrients as well as the chemical heterogeneity within each class of compounds and the complex interactions of the above variables. The major nutritional changes which occur in foods due to microbiological, enzymatic and chemical reactions are listed in below Table.

Type of change	Nutritional quality related changes in food		
Microbiological	Growth or presence of toxicogenic and/or infective microorganisms		
Enzymatic	<ol style="list-style-type: none"> 1. Hydrolytic reactions catalyzed by lipases, proteases, etc. 2. Lipoxygenase activity 		
Chemical	<ol style="list-style-type: none"> 1. Oxidative rancidity 2. Non-enzymatic browning 3. Nutrient losses <p>Foods contaminated with microorganisms may cause food borne illness. Food borne illnesses can be classified as food infection and food intoxication. Food infection occurs due to growth of pathogenic microorganisms in victim's digestive tract causing diarrhea, vomiting, fever etc. For example- Salmonellosis due to consumption of Salmonella sp. contaminated food. Food intoxication or poisoning is caused due to ingestion of food containing toxic compounds produced by pathogenic microorganisms in food. E.g. Staphylococcus aureus and Clostridium botulinum causes food poisoning. Measures for the prevention of food spoilage: Manipulation of factors controlling the conditions required for microbial growth and enzyme action viz. temperature, moisture, air and pH other than the food itself can help prevent food spoilage.</p>		

ROLE OF MICROORGANISMS IN FOOD SPOILAGE

- Food spoilage means the original nutritional value, texture, flavor of the food are damaged, the food become harmful to people and unsuitable to eat.
- Microbial spoilage:
- There are three types of microorganisms that mostly cause food spoilage .
 - yeasts
 - moulds
 - bacteria

- Storage rot in grapes caused by *Botrytis cinerea*.



- Blue mould rot in tomato caused by *Penicillium* spp. (also by *Fusarium* spp.)



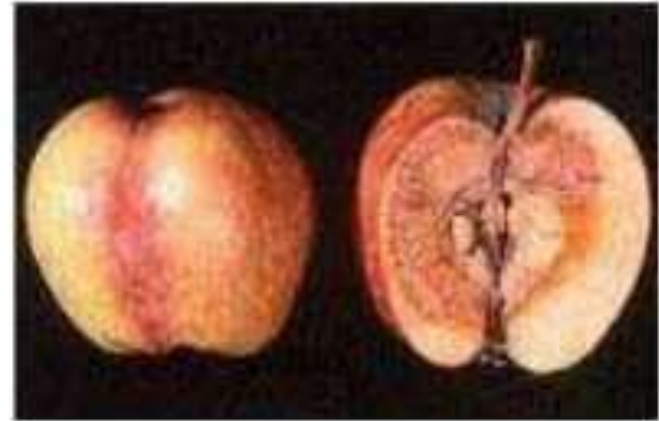
- Storage rot in strawberry caused by *Botrytis cinerea*.



- Blue mould on oranges caused by *Penicillium digitatum*.



- Watery soft rot in apple caused by *Sclerotinia sclerotiorum*.



- Black mummy rot of grapes caused by *Guignardia bidwellii*.



FOOD BORN INTOXICATIONS AND INFECTIONS

Food borne infections

- Food borne infections are caused by the **entrance of pathogenic microorganisms contaminating food into the body**, and the reaction of the body tissues to their presence.
- These can either be fungal, bacterial, viral or parasitic
- Food borne infections tend to have **long incubation periods** and are usually characterized by **fever**



FOOD BORNE DISEASE

Food-borne infection

BACTERIAL	PARASITIC
1. Typhoid	1. Ascariasis
2. Cholera	2. Amoebiasis
3. Bacillary Dysentery	3. Trichinosis
4. Salmonella infection	4. others
5. Others	

○ Food Born Intoxications

- Ingestion of toxins in foods in which microbes have grown
- Include staphylococcal food poisoning, botulism, Clostridium perfringens food poisoning, and becillus cereus food poisoning



FOOD BORNE DISEASE

Food poisoning or food intoxication

Bacterial	Plant and animals	Chemical
<ol style="list-style-type: none">1. Staphylococcus2. C. Botulium3. Streptococcus	<ol style="list-style-type: none">1. Some mushrooms2. Some mussels3. Certain herbs4. Some fishes5. Others	<ol style="list-style-type: none">1. Arsenic2. Lead3. Cadmium4. Cyanide5. Antimony6. Nitrites7. DDT.ETC

FOOD PRESERVATION

○ Removal of microorganisms

- Usually achieved by filtration
- Commonly used for water, beer, wine, juices, soft drinks, and other liquids

○ Low temperature

- Refrigeration at 5°C retards but does not stop microbial growth
- Microorganisms can still cause spoilage with extended spoilage
- Growth at temperatures below -10°C has been observed



FOOD PRESERVATION

○ Canning

- Food heated in special containers (retorts) to 115°C for 25 to 100 minutes
- Kills spoilage microbes, but not necessarily all microbes in food

○ Pasteurization

- Kills pathogens and substantially reduces number of spoilage organisms
- Different pasteurization procedures heat for different lengths of time
- Shorter heating times result in improved flavor



FOOD PRESERVATION

○ Reduced water availability

- Drying
- Freeze-drying (lyophilization)
- Addition of high concentrations of solutes such as sugar or salt

○ Chemical-Based preservation

- GRAS
 - chemical agents "generally recognized as safe"
- pH of food impacts effectiveness of chemical preservative



FOOD PRESERVATION

○ Radiation

- Ultraviolet (UV) radiation
 - used for surfaces of food-handling equipment
 - does not penetrate foods
- Radappertization
 - use of ionizing radiation (gamma radiation) to extend shelf life or sterilize meat, sea foods, fruits and vegetables

○ Microbial Product-Based Inhibition

- Bacteriocins: bactericidal proteins active against related species
- Some dissipate proton motive force of susceptible bacteria



CONCLUSION

Microorganisms plays a vital Role in food processing, spoilage and preservation. Not only today but from ancient times processing and preservation of foods by fermentation techniques have been done using ancient technologies. Fermentation techniques not only increased shelf life and microbial safety of a food, but also make some food more tasty and digestible.