COURSE TITLE: FOOD AND INDUSTRIAL MICROBIOLOGY
COURSE NO. - DTM-321: CREDIT HRS-3 (2+1)

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INTRODUCTION TO FOOD MICROBIOLOGY BACTERIA

1. Introduction 2. Important development of early food microbiology 3. Historical developments in food microbiology 4. Scope of food microbiology 5. Significance of microorganisms in foods 5.1 Microbes and Disease 5.2 Microbes and Food Spoilage 5.3 Microbes and Food fermentation 5.4 Microbes and Food Preservation

SCOPE OF FOOD MICROBIOLOGY:
BASIC ASPECTS, HISTORY AND SCOPE OF FOOD MICROBIOLOGY

Introduction

FOOD SCIENCE IS A DISCIPLINE CONCERNED WITH ALL ASPECTS OF FOOD STARTING AFTER HARVESTING AND ENDING WITH CONSUMPTION BY THE END USER - CONSUMER. THE FIELD OF FOOD MICROBIOLOGY IS A VERY BROAD ONE, ENCOMPASSING THE STUDY OF MICROORGANISMS WHICH HAVE BOTH BENEFICIAL AND DELETERIOUS EFFECTS ON THE QUALITY AND SAFETY OF RAW AND PROCESSED FOODS. IT IS IMPORTANT TO UNDERSTAND THE RELATIONSHIPS AMONG THE VARIOUS MICROORGANISMS MAKING UP THE MICROFLORA OF A FOOD. INFANT FOOD MICROBIOLOGISTS ARE CONCERNED WITH THE PRACTICAL IMPLICATIONS OF THE MICROFLORA OF THE FOOD AND THE FOOD MICROORGANISMS THAT CAN CAUSE SPOILAGE OF FOOD AND DISEASE IN HUMANS.

INTRODUCTION

Food microbiology covers areas of food and fermentation microbiology.

- It focuses on the study of microbial ecology related to foods like spoilage, fermentation, preservation, investigation of foodborne outbreaks and national and international Food Legislation.
- Developments which stretched over several centuries eventually led to the recognition of the importance and role of microorganisms in foods and products.

IMPORTANT DEVELOPMENT OF EARLY FOOD MICROBIOLOGY

Following types of discoveries explored the way for the establishment of early food microbiology in the 20th century:

- Agriculture and animal husbandry were adopted by the early civilizations around 8000 B.C.
- Persevere the food: Between 8000 and 1000 B.C. drying, cooking, baking, smoking, salting, sugaring with honey, ice, storage in pits, fermentation with fruits, grains and milk.
- Acceptance of existence of bacteria and yeasts by Leeuwenhoek around the 1670s.
- In 1870s, Pasteur initiated the possible roles of microorganisms in foods.

HISTORICAL DEVELOPMENTS IN FOOD MICROBIOLOGY

- Few major developments and most significant dates, events and contributions of scientist in the
- History of spoilage
- Food poisoning
- Preservation of food
- Microbiological techniques
- Food legislation.

Scope of Food Microbiology

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SIGNIFICANCE OF MICROORGANISMS IN FOODS

- Microorganisms as causative agents of disease in humans--foodborne pathogens.
- Microorganisms and food spoilage
- Microorganisms as food sources.
- Microorganisms exploited for the production of food.

HISTORICAL DEVELOPMENTS -1

Although it is extremely difficult to pinpoint the precise beginnings of human awareness of the presence and role of microorganisms in foods, the available evidence indicates that this knowledge preceded the establishment of bacteriology or microbiology as a science. Some of the more significant dates and events in the history of food preservation, food spoilage, food poisoning are

In1782 Canning of vinegar was introduced by a Swedish chemist. 1813 Use of SO2 as a meat preservative is thought to have originated around this time 1839 Tin cans came into wide use in the United States. 1840 Fish and fruit were first canned. 1853 R. Chevallier-Appert obtained a patent for sterilization of food by autoclaving. 1854 Pasteur began wine investigations. Heating to remove undesirable organisms was introduced commercially in 1867- 1868. 1855 Grim wade in England was the first to produce powdered milk. 1865 The artificial freezing of fish on a commercial scale was begun in the United States. Eggs followed in 1889. 1880 The pasteurization of milk was begun in Germany. 1882 Krukowitsch was the first to note the destructive effects of ozone on spoilage bacteria. 1890 Mechanical refrigeration for fruit storage was begun in Chicago. 1907 E. Metchnikoff and co-workers isolated and named one of the yogurt bacteria, Lactobacillus bulgaricus. 1908 Sodium benzoate was given official sanction by the United States as a preservative in certain foods. 1928 The first commercial use of controlled atmosphere storage of apples was made in Europe (first used in New York in 1940)

HISTORICAL DEVELOPMENTS -2

1908 Sodium benzoate was given official sanction by the United States as a preservative in certain foods. 1928 The first commercial use of controlled atmosphere storage of apples was made in Europe (first used in New York in 1940) 1950 The D value concept came into general use.

1680 Leeuwenhoek was the first to observe yeast cells. 1780 Scheele identified lactic acid as the principal acid in sour milk. 1857 Pasteur showed that the souring of milk was caused by the growth of organisms in it. 1873 The first reported study on the microbial deterioration of eggs was carried out by Gayon. — Lister was first to isolate Lactococcus lactis in pure culture. 1888 Miquel was the first to study thermophilic bacteria. 1895 S.C. Prescott and W. Underwood traced the spoilage of canned corn to improper heat processing for the first time. 1915 Bacillus coagulans was first isolated from coagulated milk by B. W. Hammer.

1857 Milk was incriminated as a transmitter of typhoid fever by W. Taylor of Penrith, England. 1888 Gaertner first isolated Salmonella enteritidis from meat that had caused 57 cases of food poisoning. 1896 Van Ermengem first discovered Clostridium botulinum. 1906 Bacillus cereus food poisoning was recognized 1937 Paralytic shellfish poisoning was recognized. 1955 Similarities between cholera and Escherichia coli gastroenteritis in infants were noted by S. Thompson. 1960 The production of aflatoxins by Aspergillus flavus was first reported.

Scope of study in Food Microbiology

1.BACTERIA--bacteriology
2.FUNGI--mycology
3.PROTOZOA—parasitology
4.ALGAE
5.VIRUSES--virology (although not a cellular entity but an intracellular parasite)
6. WORMS—parasitology (helminthology) -- not true micro- organisms—but included in food/medical microbiology
7. PRIONS—pathogenic neural derived proteins
8. EPIDEMIOLOGY—study of the source and prevalence of disease

Why study Food Microbiology??

Microorganisms as causative agents of disease in humans—food born pathogens Microorganisms and food spoilage Microorganisms as food sources Microorganisms exploited for the production of food Microbes and Agriculture. Agents of Disease (Food born Pathogens) BACTERIA E coli O157:H7, Salmonella spp., Vibrio cholera, Bacillus cereus, Clostridium botulinum, Listeria monocytogenes, Staphylococcus aureus VIRUSES Enteroviruses, Norwalk virus, Hepatitis virus PRIONS Mad Cow Disease (BSE) and Creutzfeldt-Jakob Disease PROTOZOA Giardia lamblia, Cryptosporidium parvum, Entamoeba histolyticum, Cyclospora cayetanesis HELMINTHS Tapeworms (Beef, Fish and Pork), Flukes (Fish and Shellfish), Roundworms and Hookworms

Why study Food Microbiology??

Food Spoilage Fungi— Bread and Cheese

Bacteria — Erwinia caratova soft rot in carrots and cucumbers

Microbes we can eat Fungi: Mushrooms are actually a microorganism— although the fruiting body is macroscopic!!! Yeasts: Vegemite (Yeast Paste) Bacteria: Spirulina platensis (a cyanobacterium) Algae: Chlorella (fresh water), Dunaliella (salt water)

Microbes that we can exploit—cheese, yogurt, vinegar, bread and sauerkraut production

Yeasts—bread, beer, liqueurs, wine

Molds--cheeses

Bacteria in agriculture Rhizobium spp: Nitrogen fixation in root nodules of legumes alfalfa etc. Bacteria used in engineering produce that is resistant to adverse environmental conditions, pests pathogens and spoilage

List of Baccteria associated with food

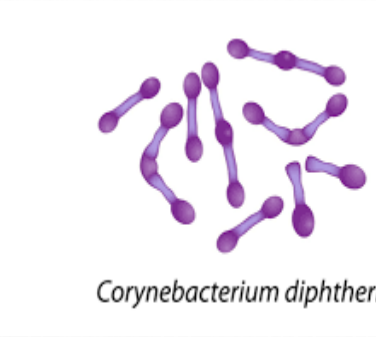
1 *Acinetobacter*
2 *Bacillus cereus*
3 *Bacillus subtilis*
4 *Carnobacterium*
5 *Corynebacterium*
6 *Clostridium perfringens*
7 Clostridium botulinum
8 Campylobacter
9 Erwinia
10 *Enterococcus* (*E. faecium, E. faecalis)*
11 *Escherichia coli*
12 *Lactococcus*
13 *Lactobacillus*
14 *Leuconostoc*
15 *Listeria monocytogenes*
16 *Micrococcus*
17 *Proteus*
18 *Propionibacterium* spp. (*P. freudenreichii*)
19 *Pediococcus* spp. (*Pediococcus pentosaceus, P. acidilactici*)
20 *Pseudomonas fluorescens*
21 *Pseudomans aeruginosa*
22 *Salmonella* (*S. typhimurium, S. typhi, S.enteritidis*)
23 *Serratia*
24 *Streptococcus thermophilus*
25 *Staphylococcus aureus*
26 *Shigella*
27 *Vibrio*
28 *Yersinia*

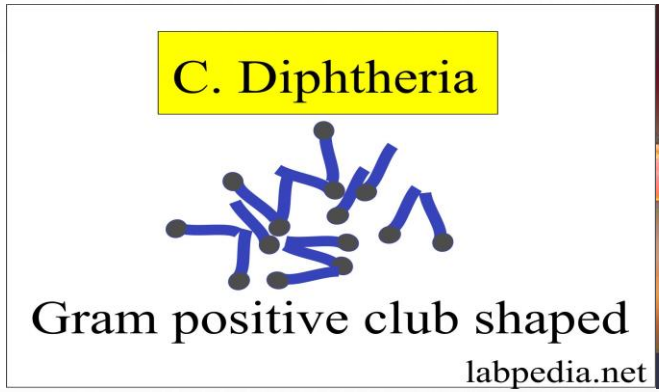
Bacillus cereus

B. cereus is a thick long rod-shaped Gram positive, catalase positive aerobic spore former and the organism is important in food borne illness. It is a normal inhabitant of soil and is isolated from a variety of foods. It is quite often a cause of diarrheal illness due to the consumption of desserts, meat, dishes, dairy products, rice, pasta etc that are cooked and kept at room temperature as it is thermoduric. Some of the *B. cereus* strains are psychrotrophic as they grow at refrigeration temperature. *B. cereus* is spread from soil and grass to cows udders and into the raw milk. It is also capable of establishing in cans. It is also capable of producing proteolytic and amylolytic enzymes and also phospholipase C (lecithinase). The production of these enzymes by these organisms can lead to the spoilage of foods. The diarrheal illness is caused by an enterotoxin produced during the vegetative growth of *B. cereus* in small intestine. The bacterium has a maximum growth temperature around 48°C to 50°C and pH range 4.9 to 9.3. Like other spores of mesophilic *Bacillus* species, spores of *B. cereus* are also resistant to heat and survive pasteurization temperature.

Bacillus subtilis

Bacillus subtilis, known also as the hay bacillus or grass bacillus , is a Gram positive, catalase positive bacterium commonly found in soil. A member of the genus *Bacillus*, *B. subtilis* is thin short rod shaped, and has the ability to form a tough, protective endospore, allowing the organism to tolerate extreme environmental conditions. *B. subtilis* produces the proteolytic enzyme subtilisin. *B. subtilis* spores can survive the extreme heat during cooking. *B. subtilis* is responsible for causing ropiness a sticky, stringy consistency caused by bacterial production of long chain polysaccharides in spoiled bread dough. A strain of *B. subtilis* formerly known as *Bacillus natto* is used in the commercial production of the Japanese food *natto*, as well as the similar Korean food *cheonggukjang*. It is used to produce amylase and also used to produce hyaluronic acid, which is useful in the joint care sector in healthcare.



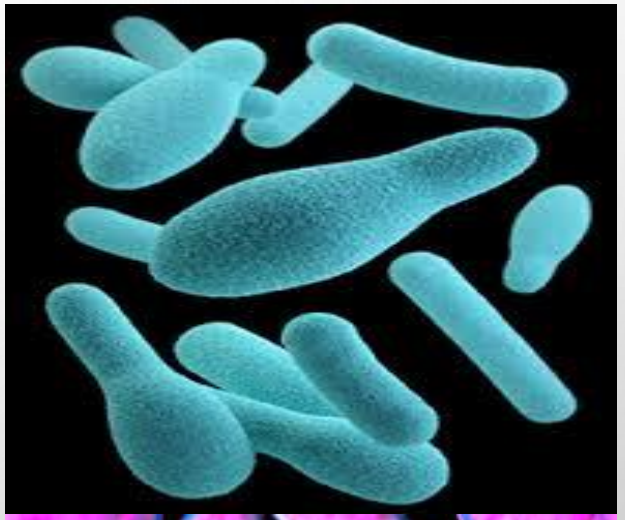


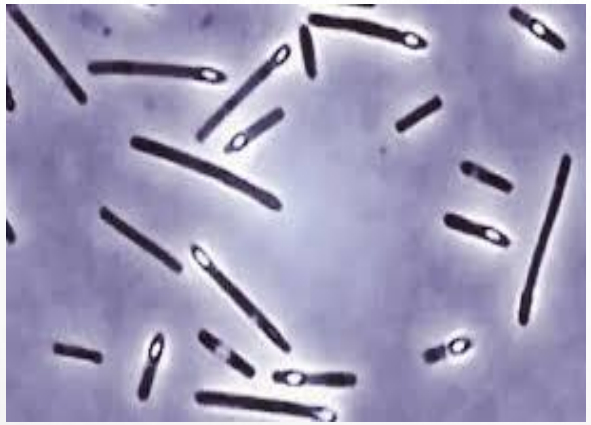
Corynebacterium

Corynebacterium is a genus of Gram positive rod shaped bacteria. They are widely distributed in nature and are mostly innocuous. Some are useful in industrial settings such as *C. glutamicum*. Others can cause human disease. *C. diphtheriae*, for example, is the pathogen responsible for diphtheria. Some species are known for their pathogenic effects in humans and other animals. Perhaps the most notable one is *C. diphtheriae*, which acquires the capacity to produce diphtheria toxin only after interacting with a bacteriophage. Diphtheria toxin is a single, 60,000 molecular weight protein composed of two peptide chains, fragment A and fragment B, held together by a disulfide bond.

Clostridium botulinum

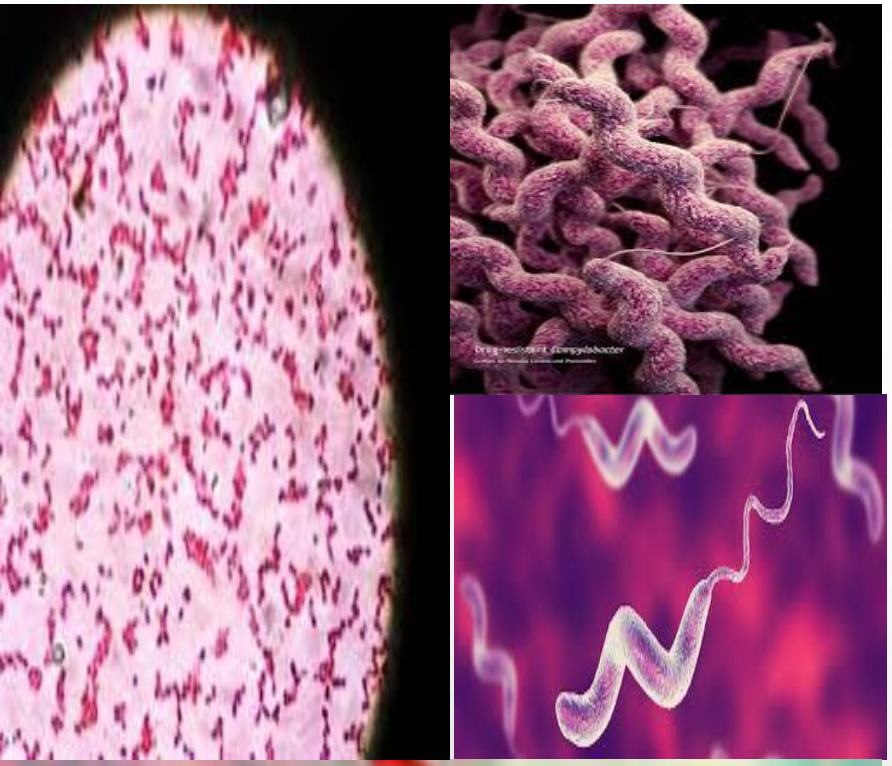
C. botulinum produces the most potent toxin known. It is a Gram-positive anaerobic rod-shaped bacterium. Oval endospores are formed in stationary phase cultures. There are seven types of *C. botulinum* (A to G) based on the serological specificity of the neurotoxin produced. Botulism is a rare but very serious disease. The ingestion of neurotoxin produced by the organism in foods can lead to death. However, the toxin (a protein) is easily inactivated by heat. The organism can grow at temperature ranging from 10-48°C with optimum growth temperature at 37°C. Spores are highly heat resistant. The outgrowth of spores is inhibited at pH < 4.6, NaCl> 10% or water activity< 0.94. Botulinum spores are probably the most radiation resistant spores of public health concern. Contamination of foods is through soil and sediments where they are commonly present. The organism grows under obligate anaerobic conditions and produces toxin in under processed (improper canning) low acid foods at ambient temperature.





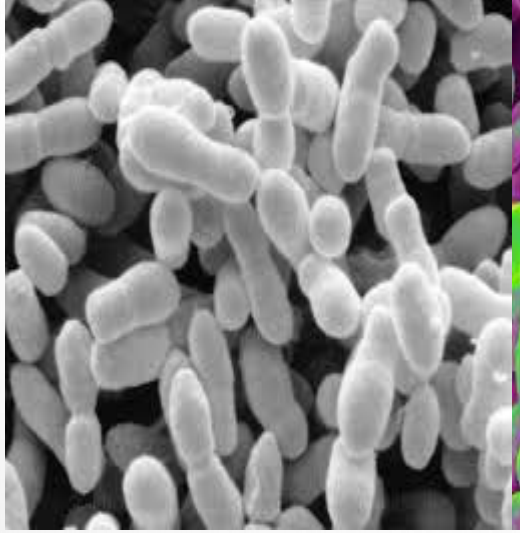
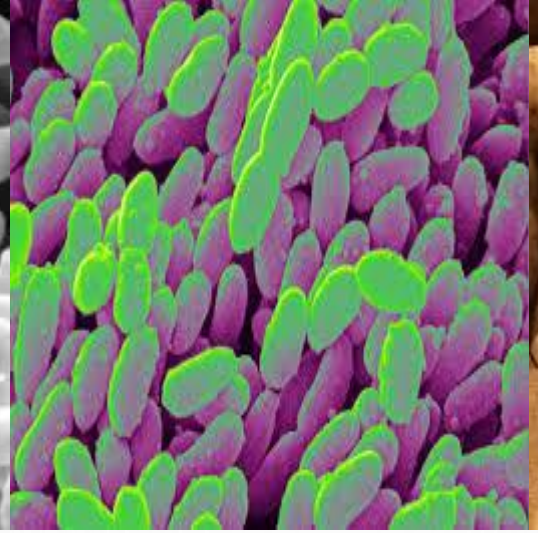
Clostridium perfringens

C. perfringens is a Gram positive encapsulated anaerobic nonmotile bacterium commonly found on meat and meat products. It has the ability to cause food borne disease. It is a toxin producing organism produces *C. perfringens* enterotoxin and β toxin that are active on the human GI tract. It multiplies very rapidly in food (doubling time < 10 min). Spores are resistant to radiation, desiccation and heat and thus survive in incompletely or inadequately cooked foods. However, it tolerates moderate exposure to air. Vegetative cells of *C. perfringens* are also somewhat heat tolerant as they have relatively high growth temperature (43°C -45°C) and can often grow at 50°C. They are not tolerant to refrigeration and freezing. No growth occurs at 6 °C . *C. perfringens* is present in soil and the other natural environment.



Campylobacter

Campylobacter are Gram negative non spore forming rods. *Campyloleacter jejuni* is an important food borne pathogen. It is one of the many species within the genus *Campylobacter*. *Campylobacter* species *C. jejuni* and *C. coli* cause diarrhea in humans. The organism is heat sensitive (destroyed by milk pasteurization temperature). It is also sensitive to freezing. The organism belongs to the family *Campylobactereaceae*. The organisms are curved, S shaped, or spiral rods that may form spherical or coccoids forms in old cultures or cultures exposed to air for prolonged periods. Most of the species are microaerophilic. It is oxidase and catalase positive and does not grow in the presence of 3.5% NaCl or at 25 °C or below. The incidence reported for gastro enteritis by this organism are as high as in case of *Salmonella*. The organism is commonly present in raw milk, poultry products, fresh meats, pork sausages and ground beef. The infective dose of *C. jejuni* may be <1,000 organisms.

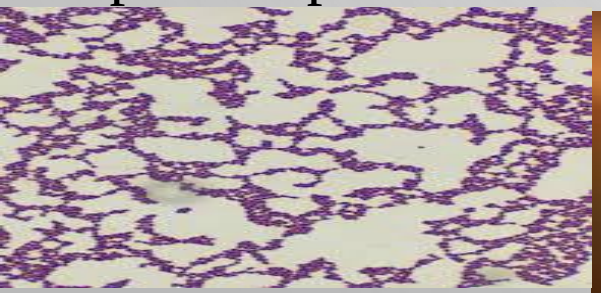
Erwinia

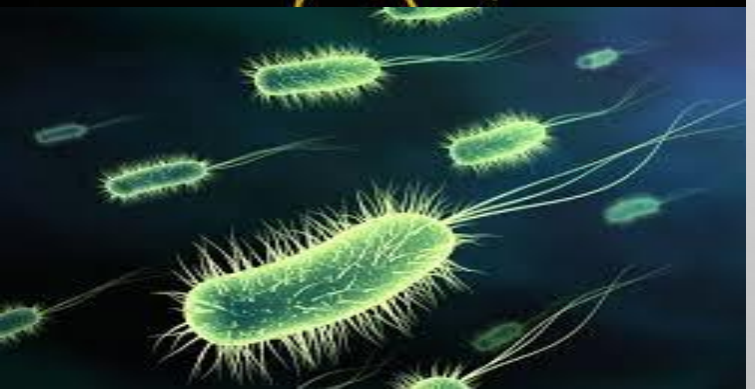
Erwinia is a genus of the family *Enterobacteriaceae* bacteria containing mostly plant pathogenic species. The organisms was named after the first phyto bacteriologist, Erwin Smith. It is a Gram negative bacterium related to *E. coli*, *Shigella*, *Salmonella* and *Yersinia*. It is primarily a rod shaped bacterium. A well known member of this genus is the species *E. amylovora*, which causes fire blight on apple, pear and other Rosaceous crops. *Erwinia carotovora* (also known as *Pectobacterium carotovorum*) is another species, which causes diseases in many plants. These species produce pectolytic enzymes that hydrolyze pectin between individual plant cells. . Decay caused by *E. carotovora* is often referred to as bacterial soft rot (BSR). Most plants or plant parts can resist invasion by the bacteria, unless some type of wound is present. High humidity and temperature around 30°C favor development of decay.

Enterococcus (E. faecium, E. faecalis)

Enterococcus is a genus of lactic acid bacteria. Enterococci are Gram positive cocci that often occur in pairs (diplococci) or short chains and are difficult to distinguish from streptococci on physical characters mentioned above. The two species are commensal organisms in the intestine of humans. The Enterococci are facultative anaerobic organisms non spore forming that grows optimally at 35°C. However, they tolerate wide range of environmental conditions (10-45°C) pH (4.5 to 10.5) quite high NaCl concentration (6.5%) and can survive heating at 60°C for 30 min. Catalase negative, oxidase negative bacteria of the genes *Enterococcus* are ubiquitous organisms that often occur in large numbers on vegetables, plant materials and foods

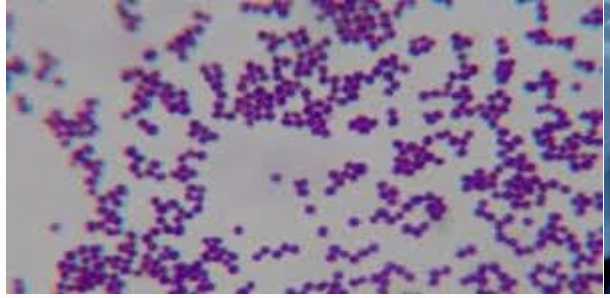
especially those of animal origin such as meat and dairy products. Enterococci also constitute a large preparation of autochthonous bacteria associated with the mammalian gastrointestinal tract. The resistance of enterococci to pasteurization temperatures and their adaptability to different substrates and growth conditions in food products manufactured from raw materials and in heat treated food products is of great significance. Enterococci may constitute an important part of the microflora of fermented cheese and meats.



Escherichia coli

E. coli strains are associated with food borne gastroenteritis. These are Gram negative asprogeneous rods that ferment lactose and produce dark colonies with a metallic sheen on Endo agar. The organism grows well on a large number of media and in many foods. They grow over a wide range of temperature (4 to 46 °C) and pH (4.4 to 9.0). However, they grow very slowly in foods held at refrigerator temp. (5 °C). They belong to the family *Enterobacteriaceae*. The organism is also an indicator of fecal pollution. The organism is also capable of producing acid and gas and off flavours in foods. *E. coli* strains involved in food borne illness can be placed into five groups: enteropathogenic (EPEC), enterotoxigenic (ETEC), entero invasive (EIEC), enterohemorrhagic (EHEC) and facultatively enteropathogenic (FEEC). The organism also grows in the presence of bile salts. The primary habitat of *E.coli* is the intestinal tract of most warm blooded animals. *E.coli* 0157: H7 strains are unusually tolerant of acidic environments.



Lactococcus

L.lactis* subsp. *Lactis ***L.lactis* subsp. *Cremoris*** ***L.lactis* subsp.*lactis biovar diaectylactis***

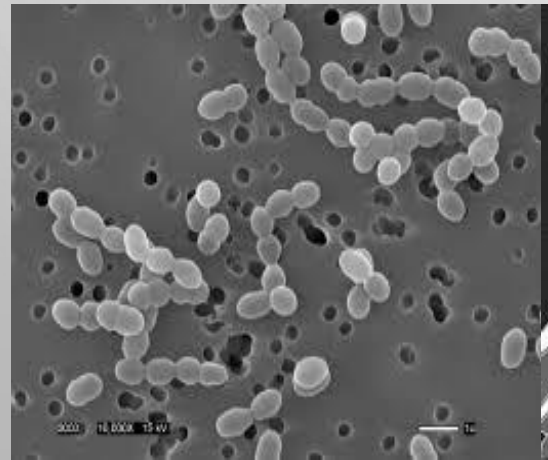
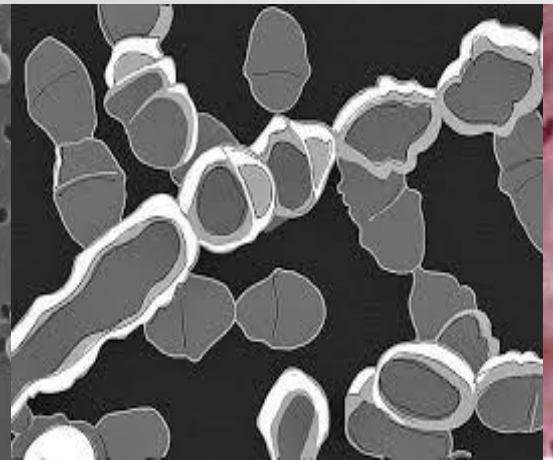
Lactococcus is a genus of lactic acid bacteria that were formerly included in the genus Streptococcus Group N (Group N Streptococci). They are known as homofermentors meaning that they produce a single product of glucose fermentation. They are Grampositive, catalase negative, nonmotile coccus that are found singly, in pairs or in chains. Some of the strains of lactococci are known to grow at or below 7 °C. Lactococci are intimately associated with dairy products. These organisms are commonly used in the dairy industry in the manufacture of fermented dairy products like cheeses. They can be used in single strain starter cultures or in mixed strain cultures with other lactic acid bacteria such as *Lactobacillus* and *Streptococcus*. Their main purpose in dairy production is the rapid acidification of milk. This causes drop in the pH of fermented product which prevents the growth of spoilage and pathogenic bacteria. These bacteria also play a role in the flavor of the final product. Dairy lactococci have also been exploited for several industrial fermentations in the biotechnology industry. They are easily grown at industrial scale up on cheap whey based media. *Lactococcus lactis* subsp. *lactis* includes species formerly designated as *S. lactis* subsp. *lactis*. *L. lactis* subsp. *cremoris* is distinguished from *L. Lactis* subsp. *lactis* by the inability to (i) grow at 40 °C (ii) grow in 4% NaCl (iii) hydrolyse arginine and (iv) ferment ribose.

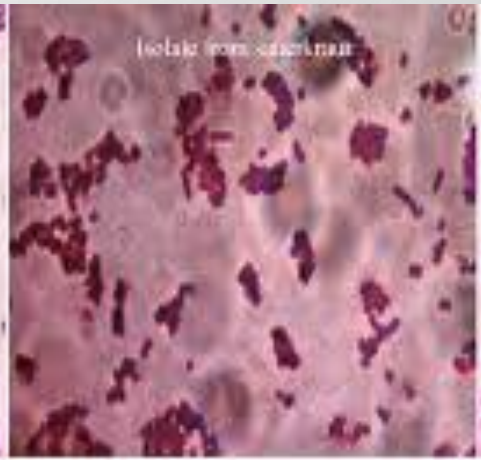
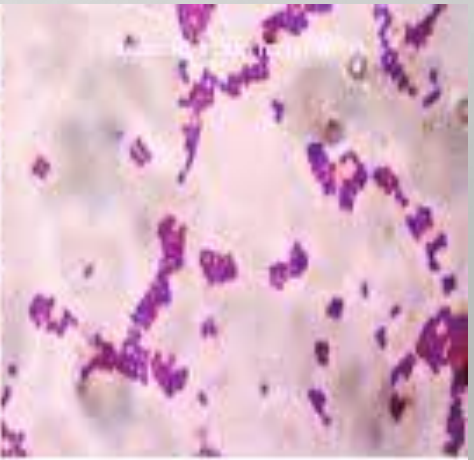
Lactobacillus (*L. bulgaricus, L. helveticus. L. plantarum, L. acidophilus, L. casei, L. lactis, L. fermentum*)

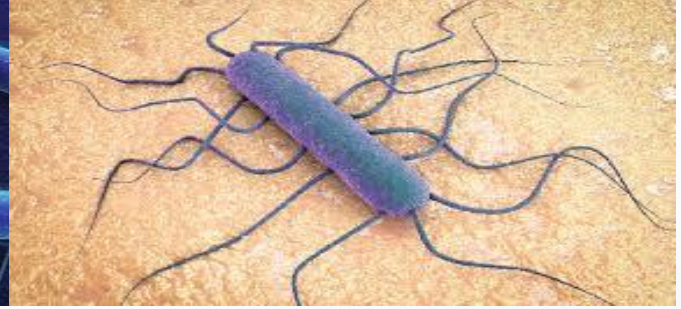
The organisms belonging to this important genus are rods usually long and slender and in some of the species form chains. They are aerotolerant/microaerophilic but some ferment sugars chiefly to lactic acids if they are homofermentative. The hetero fermentative species, besides lactic acid, also produce small amount of acetic acid, carbon dioxide and trace amounts of volatile compounds such acetaldehyde and alcohol. The homofermentative species of *Lactobacillus* include *L. bulgaricus*, *L. casei*, *L. helveticus*, *L. lactis*, *L. acidophilus* and grow optimally at 37 °C. *L. fermentum*, *L. brevis* are the typical example of hetero fermentative *Lactobacillus* and grow well at higher temperatures. Lactobacilli are of considerable importance in foods as they ferment sugar to lactic acid and other desirable flavouring compounds and are thus used in the production of fermented plant dairy and meat products. However, they are also implicated in the spoilage of wine and beer. The organism normally occurs on plant surfaces silage, manure and dairy products. Some of the strains are psychotrophic in nature and are thus involved in the spoilage of refrigerated meats. On the other hand thermoduric properties (resistance to pasteurization temperature) of some of the thermophilic strains of lactobacilli are quite useful in the manufacture of certain varieties of cheeses e.g. Swiss cheese. Some strains of lactobacilli also show probiotic attributes and are finding application in functional probiotic foods and in pharmaceutical preparations.

Leuconostoc

Leuconostoc is a genus of Gram positive bacteria, placed within the family of *Leuconostocaceae*. They are generally ovoid cocci often forming chains. *Leuconostoc* spp. are intrinsically resistant to vancomycin and are catalase negative (which distinguishes them from staphylococci). All species within this genus are heterofermentative and are able to produce dextran from sucrose. They are generally slime forming. Blamed for causing the 'stink' when creating a sourdough starter, some species are also capable of causing human infection. *Leuconostoc* spp. along with other lactic acid bacteria such as *Pediococcus* and *Lactobacillus* spp , is responsible for the fermentation of cabbage, to sauerkraut. In this process the sugars in fresh cabbage are transformed to lactic acid which give it a sour flavour and good keeping qualities.

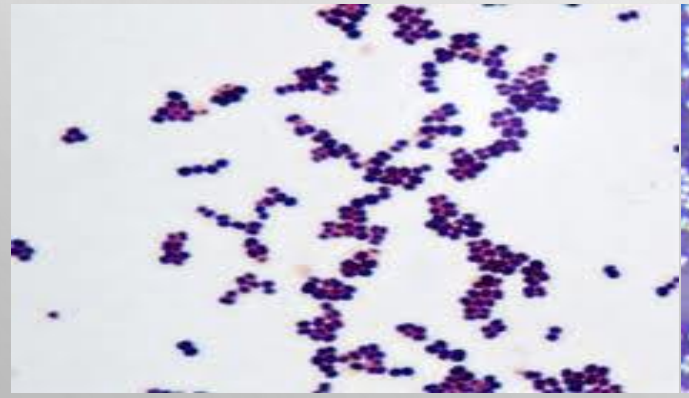
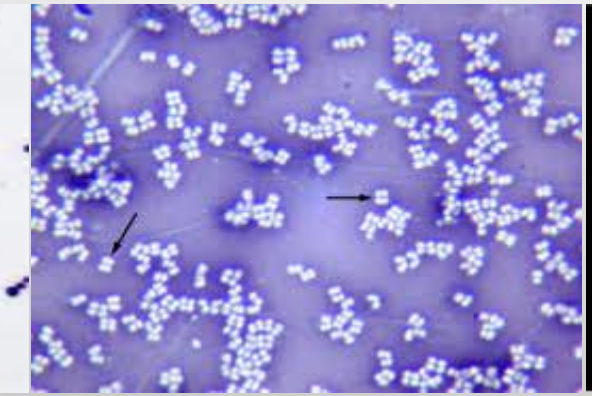


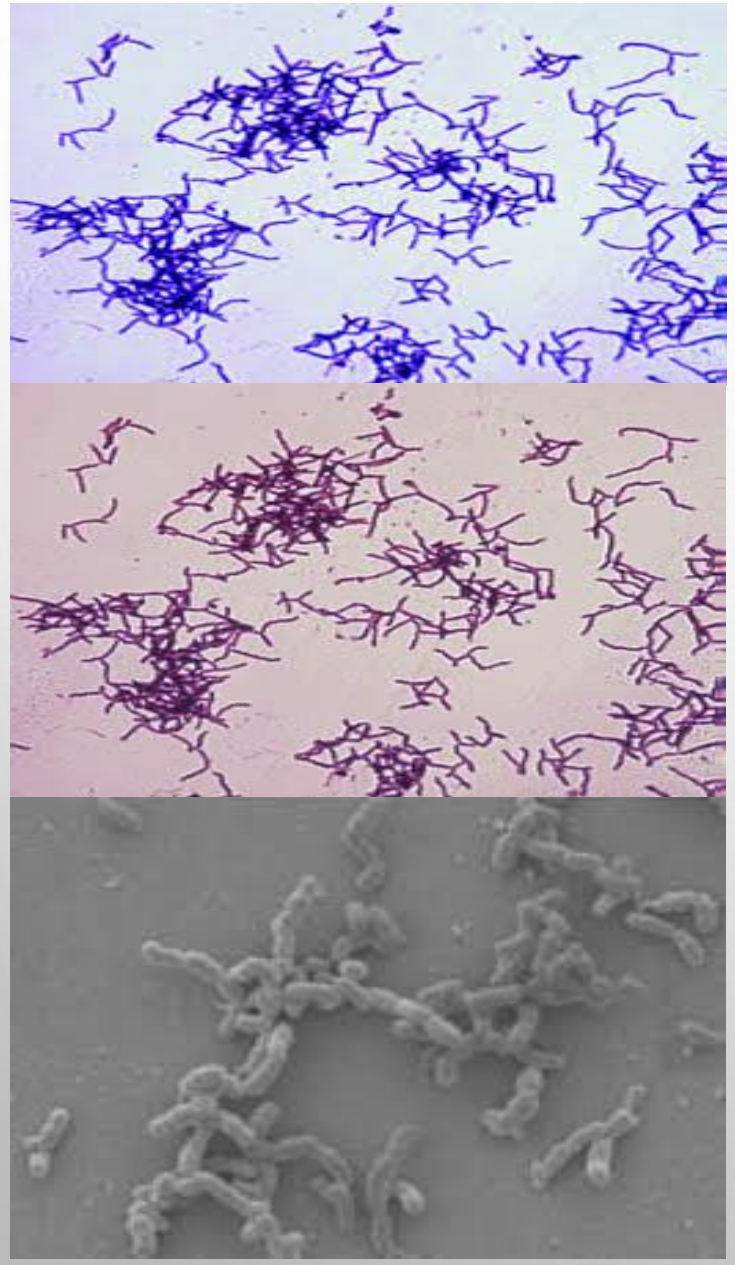
Listeria monocytogenes

Listeria monocytogenes in foods has attracted worldwide attention due to the serious illness it causes in human beings. The Listeria are Gram positive non spore forming, non-acid fast rods. The organism is catalase positive and produces lactic acid from glucose and other fermentable sugars. The organism grows well in brain heart infusion (BHI), trypticase soy, and tryptose broths. However, the medium should be fortified with B. vitamins and the amino acids. It is a mesophilic organism with optimal growth temperature 37°C but it can grow at refrigerator temperature also. Strains grows over the temperature range of 1°C to 45°C and pH range 4.1 to 9.6. *Listeria monocytogenes* is widely distributed in nature and can be isolated from decaying vegetation, soil, animal feces, sewage, silage and water. The organism has been found in raw milk, pork, raw poultry, ground beef and vegetables. The HTST treatment of pasteurization is good enough to destroy the organism in milk. The most significant virulence factor associated with *L. monocytogenes* is listerio lysin O. The virulent strains produce β hemolysis on blood agar and acid from rhamnose. *L. monocytogenes* grows well in moderate salt concentrations (6.5%). *L. monocytogenes* is unique among foodborne pathogens while other pathogens excrete toxins or multiply in the blood stream, *L. monocytogenes* enters the host's cells and grows inside the cell. In humans it crosses the intestinal barrier after entering by the oral route. Ready to Eat (RTE) foods that are preserved by refrigeration pose a special challenge with regard to *L. monocytogenes* infection.

Micrococcus

Micrococcus occurs in a wide range of environments, including water, dust, and soil. Micrococci are Gram positive spherical cells ranging from about 0.5 to 3 micrometers in diameter and typically appear in tetrads. *Micrococcus* has a substantial cell wall, which may comprise as much as 50% of the cell mass. Some species of *Micrococcus*, such as *M. luteus*, *M. roseus* (red) produce yellow or pink colonies when grown on mannitol salt agar. *Micrococcus* is generally thought to be a saprophytic or commensal organism, though it can be an opportunistic pathogen, particularly in hosts with compromised immune systems, such as HIV patients.

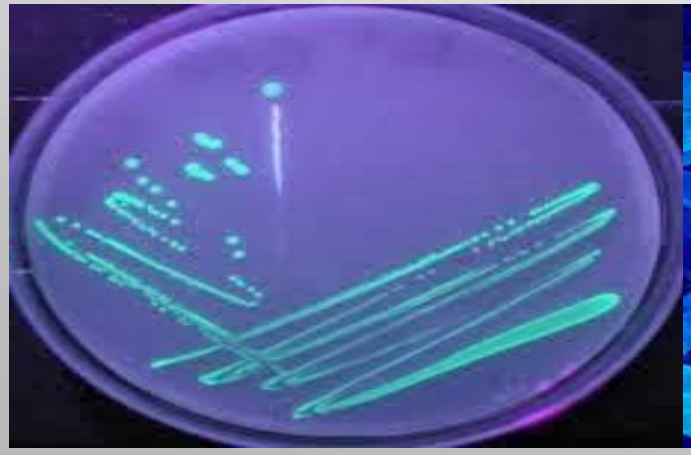
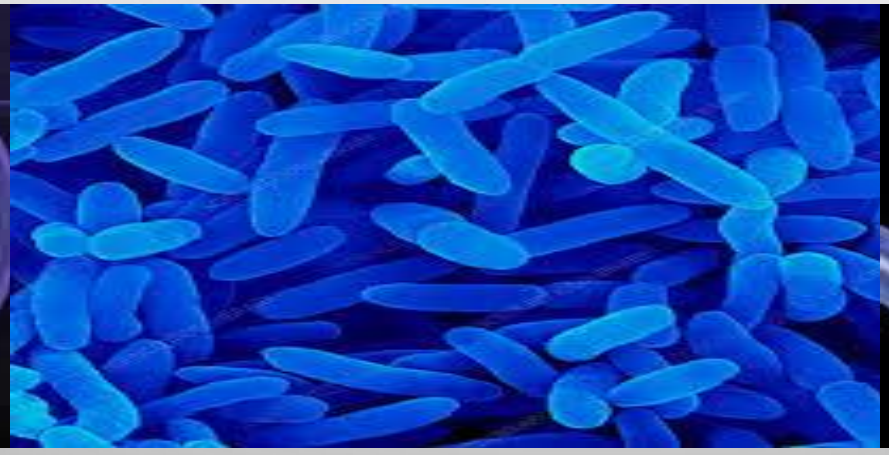
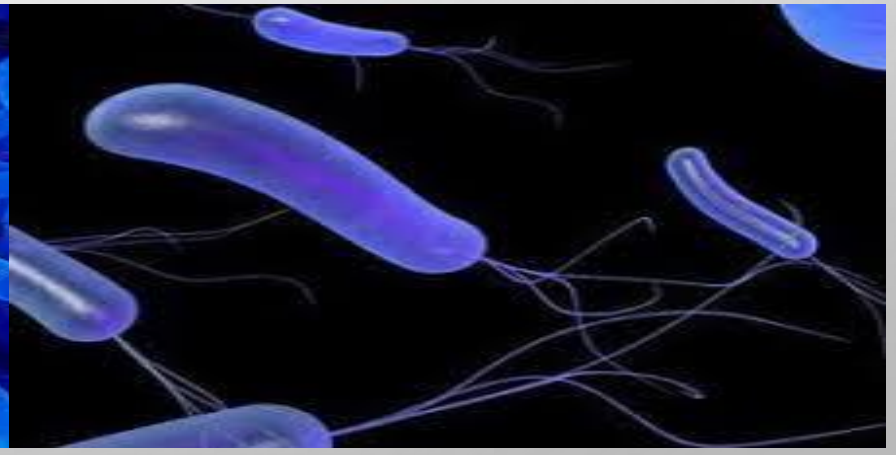


Propionibacterium spp. (P. freudenreichii)

Propionibacterium spp. are known from old time because of their use as dairy starters (especially in the production of Swiss type cheese) and their ability to produce propionic acid during growth. The genus *Propionibacterium* is generally split into “cutaneous” and “dairy” groups. The dairy *Propionibacterium* spp. can also be isolated primarily from dairy foods and silage. The species in dairy products include *P. jensenii*, *P. acidipropionici*, *P. theonii*, *P. freudenreichii*. Propionibacteria have a role in the production of flavour compounds in cheese by proteolysis and propionic acid production. Dairy strains of propionibacteria are autolytic under environmental conditions found in cheese and degrade peptides and amino acids that are present in the cheese. And the dairy species offer an interesting opportunity as novel probiotic organisms with the most obvious advantage being that they are considered safe for ingestion.

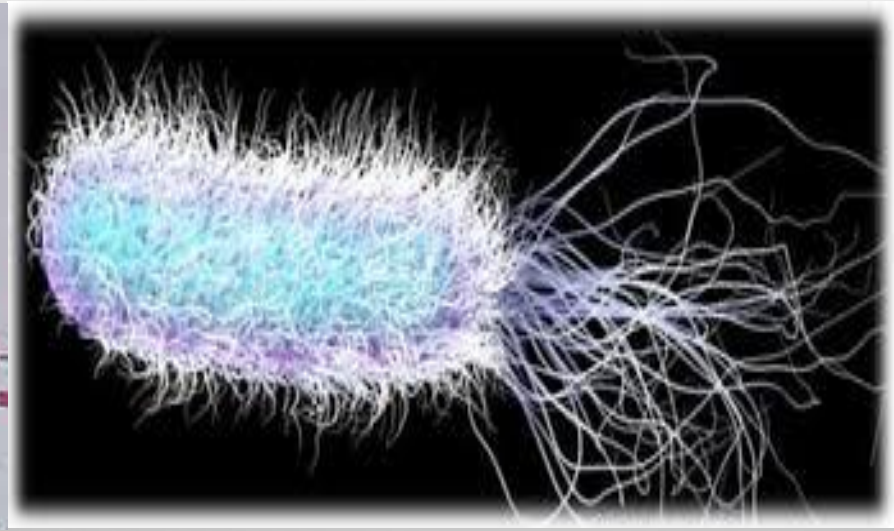
Pseudomonas fluorescens

Pseudomonas fluorescens is a common Gram negative, rodshaped, motile bacterium. The organism is psychrotrophic in nature and grows at refrigeration temperature (7°C). It has an extremely versatile metabolism, and can be found in the soil and in water. It is an obligate aerobe, but certain strains are capable of using nitrate instead of oxygen as a final electron acceptor during cellular respiration. Optimal temperature for growth of *Pseudomonas fluorescens* is 25-30 °C. It tests positive for the oxidase. *Pseudomonas fluorescens* is also a non saccharolytic organism. Heatstable lipases and proteases are produced by *Pseudomonas fluorescens* and other similar pseudomonads. These enzymes cause milk to spoil, by causing bitterness, casein breakdown, and ropiness due to the production of slime and coagulation of proteins.

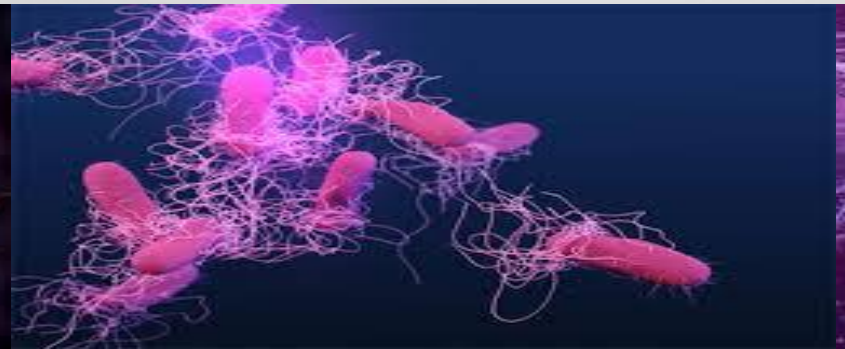
Pseudomans aeruginosa

It is a Gram negative, aerobic, rod shaped bacterium with unipolar motility. An opportunistic human pathogen, *P. aeruginosa* is also an opportunistic pathogen of plants. *P. aeruginosa* is the type species of the genus *Pseudomonas* (Migula). Gram stained *Pseudomonas aeruginosa* bacteria (pink red rods) secretes a variety of pigments, including pyocyanin (blue green), pyoverdine (yellow green and fluorescent), and pyorubin (red brown). *P. aeruginosa* is often preliminarily identified by its fluroscence and grape like or tortilla like odor *in vitro*. Definitive clinical identification of *P. aeruginosa* often includes identifying the production of pyocyanin and fluorescein, as well as its ability to grow at 42°C. *P. aeruginosa* is capable of growth in diesel and jet fuel, where it is known as a hydrocarbon using microorganism (or "HUM bug"), causing microbial corrosion. *P. aeruginosa* is considered by many as a facultative anaerobe



Salmonella (S. typhimurium, S. typhi, S.enteritidis)

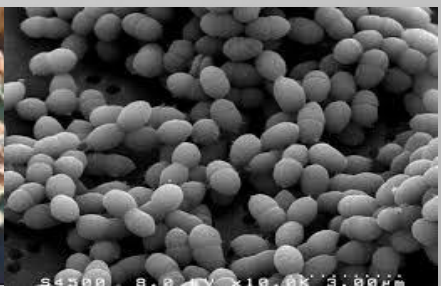
Salmonella spp. have been reported to be a leading cause of foodborne illnesses in humans. Foodborne salmonellosis scores over all other foodborne bacterial illnesses in humans. Enteric fever is a serious human disease associated with typhoid and paratyphoid strains. *SalmonellaEnterobacteriaceae*. The optimum growth temperature is 37-45°C. The organism can also grow at about 7°C in foods. I t ferments carbohydrates with its production of acid and gas. Salmonella are oxidase negative, catalase positive and grow on citrate as a sole carbon source and produce H2S. Some *Salmonella* strains can grow at higher temperatures (54 °C) while others exhibit psychrotrophic properties. The organism has the ability to grow at pH values ranging from 4.5 to 9.5, with an optimum pH growth at 6.5 to 7.5. spp. are facultatively anaerobic, small Gram negative, non spore forming, rod shaped (24 mm) bacteria belonging to the family Milk, meat and poultry are principle vehicles of human foodborne salmonellosis. Ingestion of only a few salmonella cells can be infectious. Low levels of salmonellae in a finished food products may, therefore, be of serious public health consequence.


Streptococcus thermophilus

The only *streptococcus* species that is associated with food technology is *S. thermophilus* which is used in the manufacture of yoghurt (in co culture with *L. bulgari*cus and Dahi). *S. thermophilus* is a Gram-positive facultative anaerobe and belongs to the family *Streptococcaceae*. It is catalase negative organism that is nonmotile, non spore forming and homofermentative and occurs in pairs to long chains. The spherical to avoid cells are with a diameter in the range of 0.7 to 0.9 μm. The optimum temperature for the growth of this organism is between 39°C to 45°C, although most species in the genus are able to grow at temperature ranging from 45-60°C. They do not grow at temperature below 20°C, but they can survive at 65°C for 30 min. They ferment sugars and produce around 0.6 to 0.8% lactic acid. They are able to grow in broth with 2.5% NaCl but fail to grow in 6.5% NaCl at pH 9.6 or in milk with 0.1% methylene blue (Bergey's Manual 1994). It is also classified as lactic acid bacteria (LAB). It is a very versatile organism. *S. thermophilus* has properties that make it one of the commercially most important lactic acid organism. *S. thermophilus* is used along with *Lactobacillus* spp., as a starter culture to manufacture several important fermented dairy foods including yoghurt and mozzarella cheese.



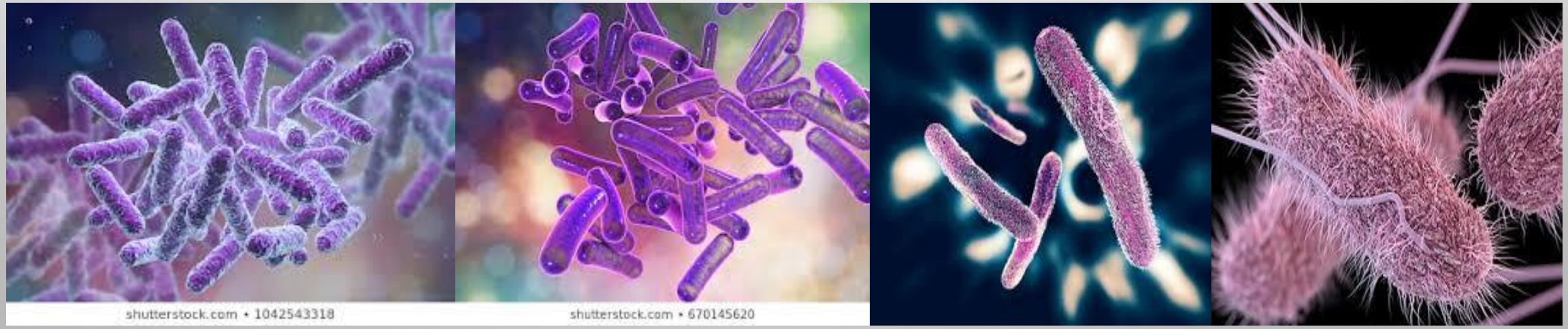


Staphylococcus aureus

Staphylococcus aureus is commonly associated with humans. It is a Gram positive Catalase positive coccus. *Staphylococcus aureus* is the common cause of foodborne gastroenteritis known as staphylococcal food poisoning. Staphylococcal gastroenteritis is caused by the ingestion of food that contains one or more enterotoxin which are produced by some strains of *S. aureus*. Although enterotoxin production is believed generally to be associated with coagulase and thermo nuclease producing *S. aureus* strains, many species of *Staphylococcus* that produce neither coagulase nor T Nase are also known to produce enterotoxin. The main reservoir of *S. aureus* is the nasal cavity of human beings from where they find their way to the skin and wounds. Mastitis in animals due to *S. aureus* is quite common and from the infected udder the organism finds its way to the milk. The organism can grow well in NaCl concentrations of 7 to 10%. Though the optimum growth temperature of the organism is 37 °C , some strains can grow at a temperature as low as 6.7 °C. The organism can grow to water activity as low as 0.86.

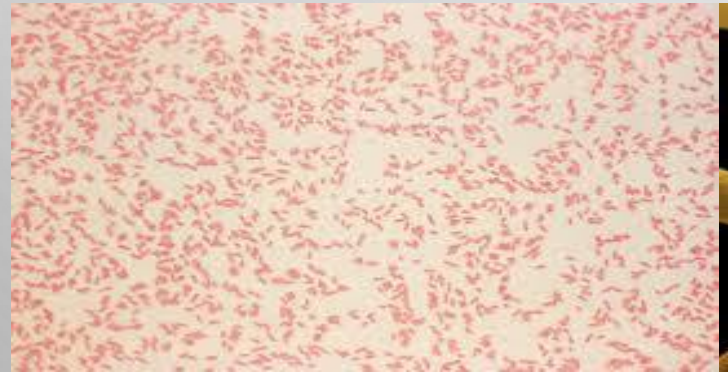
Shigella

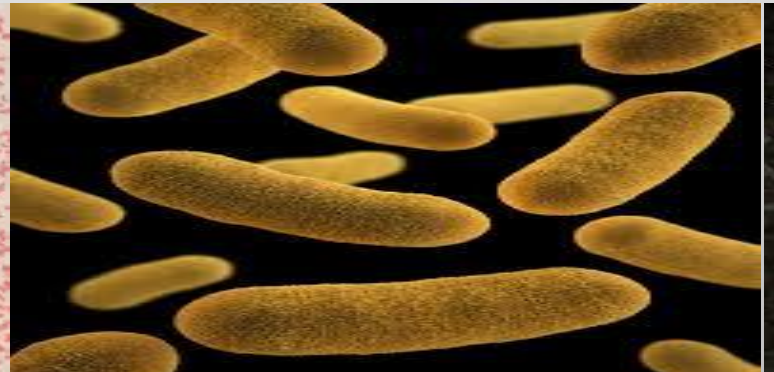
Bacillary dysentery, or shigellosis, is caused by *Shigella* species. *Shigella* is a member of the family *Enterobacteriaceae*. The growth temperature varies from 10 to 48 °C. *Shigella* does not usually survive well in low pH foods. *Shigella* is sensitive to ionizing radiations. species are nonmotile, oxidase negative produce acid only from sugars; do not grow on citrate as sole carbon source, do not grow on KCN agar. Shigellosis is an important disease in developed and developing countries. Disease is caused by ingestion of contaminated foods, and in some instances it subsequently leads to rapid dissemination through contaminated feces from infected individuals. The infective dose may be as low as 100 cells. Contamination of foods usually does not occur at the processing plant but rather through an infected food handler. Humans are the natural reservoir of Shigella. The organism is spread through the fecaloral route.

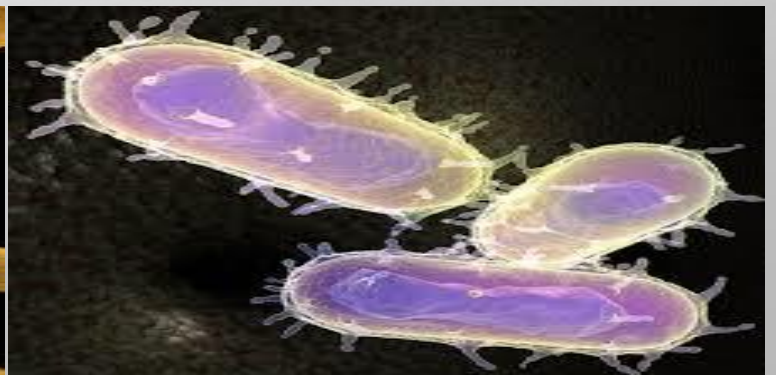


Yersinia

Yersinia enterocolitica and *Yersinia pestis* are the two important human pathogens while *Y. enterocolitica* causes food borne gastroenteritis, *Y. pestis* is an agent of human plague. *Y. enterocolitica* also known as newly emerging human pathogen is a heterogeneous species that is divisible into a large number of subgroups. *Y. enterocolitica* is unusual because it can grow at temperatures below 4°C. The generations time at the 28-30°C (Optimum growth temperature) is almost 34 min. It also survives in frozen foods. It grows better in processed foods such as pasteurized milk, vacuum packed meat, boiled eggs, boiled fish, and cottage cheese. Both the species can grow over a pH range of 4 to 10 (optimum pH is 7.6) and tolerate alkaline environment well. They can motile at a temperature < 30 °C. However, both these organisms are susceptible to pasteurization, ionizing and ultraviolet (UV) irradiation. The organism can also tolerate upto 5% NaCl. Infections with *Yersinia* species are due to transmittance of the organism from animals to humans. The organism is frequently present in pork, lamb, poultry and dairy products.







List of Yeast, mold and virus

Food Born Yeasts

Candida

Debaromyces

Kluyveromyces

Rhodotorula

Saccharomyces

Torulaspora

Food Born Molds

Alternaria

Aspergillus

Geotrichum

Mucor and Rhizopus

Food Borne Viruses

Food Born Yeasts

Yeasts have been associated with foods since ancient times, both as beneficial agents and as major causes of spoilage and economic loss. Current losses to the food and dairy industry caused by yeast spoilage are estimated at several billion dollars. As new food ingredients and new food manufacturing technologies are introduced, novel food spoilage yeasts are emerging for creating spoilage problems. To date over 70 biological species of yeasts have been described. Yeasts may be viewed as being unicellular fungi in contrast to the molds, which are multicellular.

Yeasts can be differentiated from bacteria by their larger cell size and their oval, elongate, elliptical, or spherical cell shapes.

Typical yeast cells range from 5 to 8 um in diameter, with some being even larger. Older yeast cultures tend to have smaller cells. Most of those of importance in foods divide by budding or fission. Yeasts can grow in presence of various types of organic acids such as lactic, citric and tartaric acid etc and also over a wide range of acid pH and in up to 18% ethanol. Many grow in the presence of 55-60% sucrose. Many colours are produced by yeasts, ranging from creamy to pink to red. The asco and arthro spores of some are quite heat resistant.

Candida--Members of the *Candida* genus form shining white colonies and cells contain no carotenoid pigments. *Candida tropicalis* is the most prevalent in foods in general Some members are involved in the fermentation of cocoa beans, as a component of kefir grains and many other products, including beers, and fruit juices.

Debaromyces--*Debaromyces* is one of the most important yeast genera in the dairy products. It can grow in 24% NaCl and at an aw as low as 0.65.

Kluyveromyces--*Kluyveromyces* spp. produces β galctosidase and are vigorous fermenters of sugars including lactose. *K. marxianus* is one of the two most prevalent yeasts in dairy products, kefir grain and causes cheese spoilage.

Rhodotorula--The genus *Rhodotorula* contains many psychrotrophic species that are found on fresh poultry, shrimp, fish and beef. Some grow on the surface of butter.

Saccharomyces--*Saccharomyces* are ascosporogenous yeasts that multiply by lateral budding and produce spherical spores in asci. They are diploid and do not ferment lactose. All bakers' brewers', wine and champagne yeasts are *S. cerevisiae*. They are found in Kefir grains and can be isolated from wide range of foods. *S. cerevisiae* rarely causes spoilage.

Torulaspora-- *Torulaspora* multiplies by lateral budding. They are strong fermenters of sugars. *Torula delbrueckii* is the most prevalent species.

Food Born Molds -- Molds are filamentous fungi that grow in the form of tangled mass that spreads rapidly and may cover several inches of area in a very short period. It is also referred to as mycelial growth. Mycelium is composed of branches of filaments referred to as hyphae. The molds of great importance in foods multiply by ascospores or conidia. The ascospores of some of the mold genera are notable for their extreme degrees of heat resistance.

Alternaria--*Alternaria* spp. form septate mycelia with conidiophores and large brown conidia are produced. They cause brown to black rots of fruits, apples, and figs. Some species produce mycotoxins.

Aspergillus--The *Aspergillus* spp. appear yellow to green to black on a large number of foods. Some species cause spoilage of oils. *A. niger* produces βgalactosidase, glucoamylase, invertase, lipase and pectinase. *A. oryzae* produces a amylase. Two species *A. flavus* and *A. parasiticus* produce aflatoxins, and others produce ochratoxin A and sterigmatocystin.

Geotrichum--The yeast like fungi, *Geotrichum* are also referred to as dairy mold.

Mucor and Rhizopus--*Mucor* species that produce nonseptate hyphae are prominent food spoilers. Similarly, *Rhizopus* spp. also produce non septate hyphae but give rise to stolons and rhizoids. *R. stolonifer* is by far the most common species in foods and is also referred to as “bread mold”. Other important genera of molds related to spoilage of foods are *Neurospora,Thamnidium, Trichothecium, Penicillium* and *Cladosporium* etc.

Food Borne Viruses

Viruses are filterable, ultra microscopic particles and can be cultivated only on live tissues. Viruses consist of a core of nucleic acid (DNA or RNA) and a protein coat. It is commonly believed that some of the viruses are responsible for food borne diseases in humans, particularly some nonbacterial gastroenteritis due to enteroviruses. Contaminated water and food are important carriers of hepatitis viruses. Foot and mouth disease (FMD) causing virus in cattle can be transmitted to human beings through foods. Similarly, viral diseases of poultry have also been source of ailments in humans.

THANK YOU