Food and Industrial Microbiology

Food Borne Diseases and Control

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Food Microbiology, Microbes, Food Substrates, Food Preservation, Food Spoilage, Food Borne Diseases, Food Contamination, Microbiological Safety, Quality of Foods.

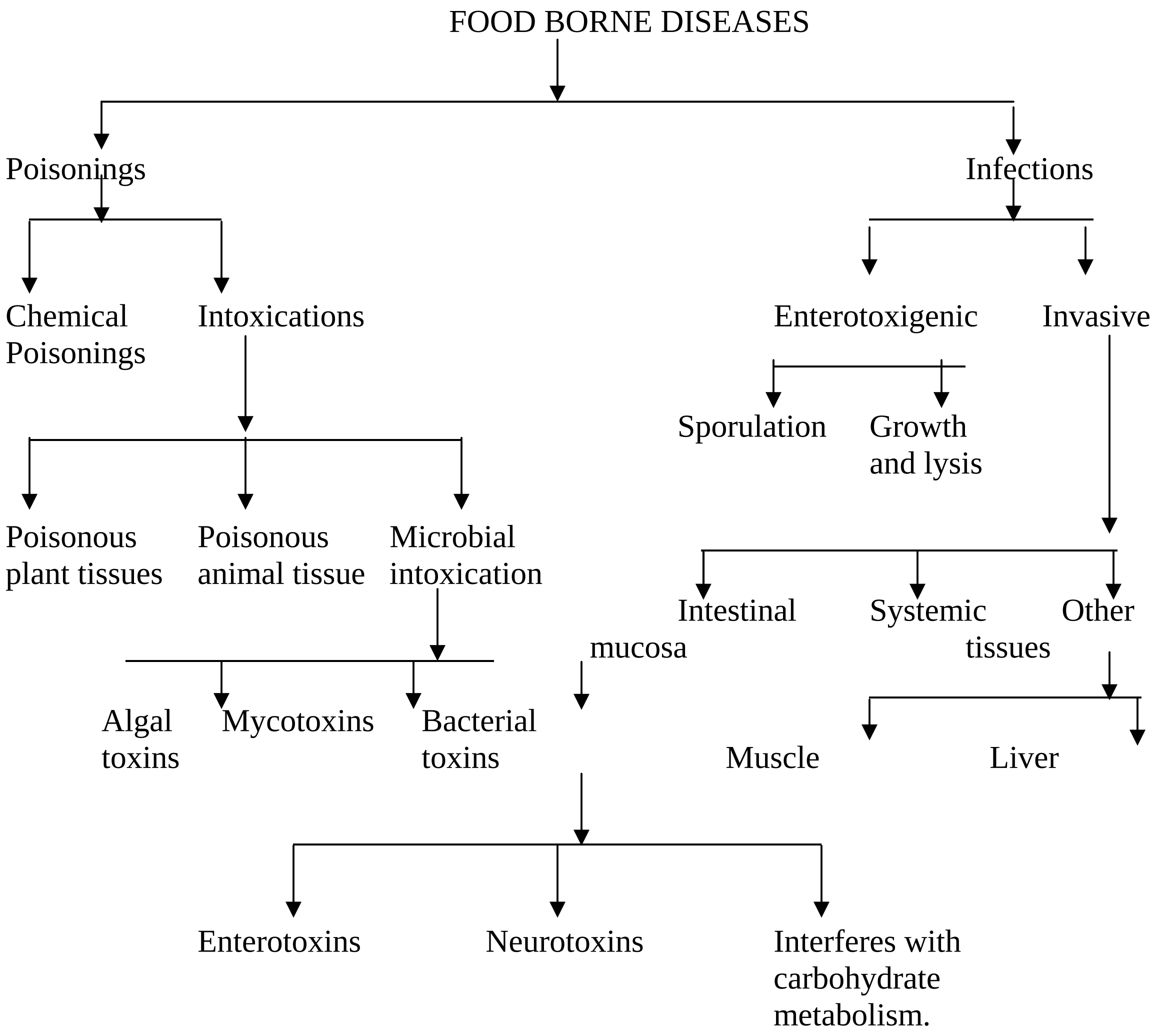
Food is the substance which gives the nutrients and energy material to living organism for its life and growth. Foods used for human beings contain carbohydrates, proteins, fats, vitamins, minerals and other growth factors. Nutritionally, human diet is more complicated than microbial nutrient requirements. Foods used for human consumption can serve as good source of nutrients for growth of microorganisms. Presence and growth of microorganisms in foods meant for human or other animal consumption makes them unfit and also serves as potential source of infections to cause a number of food borne diseases. Microorganisms enter the foods at various stages and increase their population by growth to such an extent that they become harmful on consumption of such foods. Some foods may not directly support growth of microorganisms but support them by providing an environment for their survival. Such foods are called as microbial contaminated foods. Microorganisms prolong their life in such foods and make their entry into the consumer to cause diseases subsequently. Foods may be contaminated by microorganisms and their population is increased as a result of growth in foods which serve as good growth environment. Different types of microorganisms may contaminate foods or grow in them which include bacteria, fungi, protozoans, helminths and viruses. Presence of microorganisms in foods and their growth and/or production of toxins depend on various factors. Composition of foods in terms of their nutritive value, complexity, solubility, water content or water activity, pH and several other factors contribute to the contamination, growth of microorganisms and formation of microbial products as toxins harmful to human or animal health. Food contamination or infection may occur at various stages starting from harvesting of food grains, post harvest processing, storage, food preparation for consumption, method of preparation and preservation, period of preservation, hygienic status of persons involved in processing or preparation of foods etc. Types of microorganisms and their number may also vary based on various factors as mentioned above. All these contribute to the microbiological quality of foods and their safety to the consumer.

Food poisoning

The term “food poisoning” means poisoning caused to consumer by consumption of food laden with microorganisms. It is used very loosely to include both illnesses caused by the ingestion of toxins elaborated by microorganisms and those resulting from infection of the host through the intestinal tract. Generally food poisoning occurs when people consume food containing a toxin made by a microorganism. A bacterial food intoxication therefore refers to food borne illnesses caused by the presence of bacterial toxin(s) formed in food by bacteria in food(s). A bacterial food infection refers to food borne illnesses caused by the entrance of bacteria into the body through ingestion of contaminated foods and the reaction of the body to their presence or to their metabolites.

There are several kinds of food poisoning caused by microorganisms, the most familiar examples are botulism caused by toxins of *Clostridium botulinum* and staphylococcal food poisoning due toxins produced by *Staphylococcus aureus*. Staphylococcal food poisoning is one of the most common. The most dreaded food poisoning is botulism, because of the deadly toxin produced by the causative agent. Careless storage or handling of food can cause very unpleasant and sometimes dangerous symptoms.

Food is essential for every human being for life and its contamination or infection and subsequent manifestation of diseases through food is the well known phenomenon in human health. The food borne diseases either by food infection or intoxication can be generally grouped as given below based on the causative agent and its manifestation into a disease.



Chemical food poisoning could be due to cyanide, arsenic, lead or any other poisonous chemical on their entry into the body. Poisoning due to plant tissues could be due to harmful substances present in plants and plant materials. Animal tissue poisoning could be due to tissues like skin of lizards other harmful parts animals. Microbial intoxication is by different microbial toxins produced by variety of microorganisms. Some of the algal toxins are like hepatotoxic microcystin by *Microcystis aeruginosa*, neurotoxic anatoxin A,B,C or D by *Anabaena flosaquae*. Fungal toxins or mycotoxins are highly toxic and are generally mutagenic, carcinogenic and teratogenic. Some mycotoxins are aflatoxins produced by *Aspergillus flavus*, patulin by *Penicillium expansum* and ochratoxin by *Aspergillus ochraceus*. Various bacteria are known to produce variety of toxins which are responsible for bacterial disease manifestation. Some of the important bacterial food borne diseases are given in the following paragraphs.

Food borne infections can be classified into two categories based on the criteria whether the food serves to carry microbes or culture them. (i) Those infections in which the food does not support growth of pathogens but merely carries them like in case of diphtheria, tuberculosis, infectious hepatitis etc. (ii) Those in which the food serves as a culture medium for growth of pathogens like in case of infections by *Salmonella*, *Vibrio parahaemolyticus*, enteropathogenic *E. coli* etc.

Important Diseases Caused By Food Borne Pathogens

Disease caused by *Clostridium botulinum*

Clostridium botulinum cells are anaerobic Gram-positive rods that produce heat resistant endospores. Strains of this organism are classified into seven serotypes, A – G, based on which antigenically distinct form of botulinum toxin is produced. Human botulism is caused by serotypes A, B, E and F. Serotype C and D cause botulism in chickens, ducks, horses and cattle, while serotype G has not been proved to cause disease.

Botulism

Botulism is a disease caused by the ingestion of food containing the neurotoxin produced by *Clostridium botulinum*. The organism is a rod shaped soil bacterium. It is saprophytic, spore forming, gas forming and anaerobic organism. Seven important types of toxins produced by this organism are distinguished on the basis of serological specificity. These toxins are predominantly designated by the same capital letter as given below.

Type A toxin – This is the one commonly causing human botulism in western parts of the United States. It is more toxic than type B.

Type B toxin – This is found more often than type A in most soils of the world and is less toxic to human beings.
Type C toxin – This causes botulism of fowls, cattle, milk and other animals but not of human beings so far as is known.

Type D toxin – This is associated with forage poisoning of cattle in the Union of South Africa.

Type E toxin – This is toxic for humans, has been obtained chiefly from fish and fish products.

Type F toxin – Except for its toxin it is similar to types A and B, has been isolated in Denmark and produces human botulism.

Type G toxin – This has been isolated from the soil in Argentina but has not been implicated in human botulism.

Not all types of strains produce a single toxin. For example, some type C strains produce predominately C1 toxin with smaller amounts of D and C2 or only C2. Type D strains produce predominately D toxin with lesser amounts of C1 and C2 toxins. Type A strains and most cultures of type B are proteolytic and are putrefactive enough to give an obnoxious odor to proteinaceous foods, but some strains of type B and those of type E are not. Separation of various strains of *Cl. botulinum* solely on the basis of toxin types results in many heterogeneous groups. For convenience *Cl. botulinum* strains containing milk or casein, glucose or maltose and corn steep liquor yield more potent type A toxin than other media and that potencies of toxin from the following canned foods are in descending order like corn > peas > string beans > spinach. Therefore the type of food with its composition influences the toxin production by contaminated bacterium. Strains of *Cl. Botulinum* are frequently divided into three general groups based on cultural and physiological characters. These groups are:

Group I which includes all type A strains and the proteolytic strains of B and F.
Group II includes all type E strains and the non-proteolytic strains of B and F.
Group III includes types C and D, they are non-proteolytic and share a common metabolic pattern.

Toxin production by *Cl. botulinum* depends on the ability of the cells to grow in a food and autolyze. The types A, B, E and F toxins apparently are synthesized as large, comparatively inactive proteins which become fully toxic after some hydrolysis. The factors that influence spore germination, growth and hence toxin production are of special interest. These factors include the composition of the food or its nutritive properties, moisture content, pH, oxidation-reduction potential and salt content, the temperature and time of spoilage of food. Meats, fish and low or medium acid canned foods have been found to support toxin production and to differ in the potency of toxin formed.

The other factors that influence toxin production are NaCl concentration, temperature and pH. The concentrations of sodium chloride necessary to prevent growth and toxin production in foods depends on the composition of foods and the temperature. The presence of sodium nitrate in sausage or of di-sodium phosphate in cheese spread reduce the level of sodium chloride necessary to prevent toxin production. A pH near neutrality favors *Cl. botulinum* for its growth and toxin production. A pH of 4.5 or lower will prevent toxin production in most foods, but the lowest pH for spore germination is considerably higher. A maximal pH of 8.89 was found for vegetative growth and *Cl. botulinum* has been found to be growing and producing toxin. However, in foods that normally are too acidic for it, when other microorganisms also were growing in the food and presumably raising the pH generally help growth of this organism and produce toxin.

Temperature is an important factor in determining whether toxin production will take place and if so at what would be the rate of production. A few strains have been reported to be able to grow at 10 to 11^0C, but about 15^0C has been claimed to be the lowest temperature for germination of spores. The maximal temperature for growth is about 48^0C for most of these strains and about 45^0C for type E.

The toxin of *Cl. botulinum*, a protein that has been purified and crystallized, is so powerful that only a very little amount is sufficient to cause death. It is absorbed mostly in the small intestine and paralyzes the involuntary muscles of the body. An important characteristic is its comparative thermolability. The heat treatment necessary to destroy it depends on the type of organism producing the toxin and the medium in which it is heated. In the laboratory, heat treatments of 5 to 6 min at 80^0C will inactivate type A toxin, while 15 min at 90^0C will inactivate type B toxin. The toxin can be destroyed in cheese by 7.3 Mrad of gamma rays and in broth by 4.9 Mrad. The non proteolytic strains produce toxins which are not fully activated and the addition of trypsin will result in a maximum potential for toxicity.

Botulism occurs only rarely but scope of occurrence is more and the fatality rates are higher. The foods involved are inadequately home-canned foods like jams, meats and fish, string beans, sweet corn, beets, asparagus, spinach etc. Commercially processed foods have accounted for less than 10% of the out breaks. Spores of *Cl. botulinum* will survive long storage periods in raw and precooked frozen foods. They can grow and produce toxin if foods are kept at high temperatures after thawing. The toxin produced is very potent. The typical symptoms of botulism usually appear within 12 to 36 hours. Symptoms that are manifested very early are acute digestive disorder, followed by nausea, vomiting and diarrhoea. Fatigue, dizziness, headache and finally constipation are manifested. Double vision, and difficulty in swallowing food, speaking, dryness of mouth, constriction of throat, coating and swelling of tongue are also manifested. Body temperature also varies. The toxin is a neurotoxin that paralyzes the involuntary muscles, paralysis spreads to the respiratory system and heart resulting in death mainly due to respiratory failure.

The organism *Cl. botulinum* also causes infant botulism and this was first recognized in 1970s. This is different from food borne illness in that the toxin is released in vivo after growth of the organism in the intestine. Clinical symptoms are weakness, lack of sucking, loss of head control and diminished gag reflex.
The only known treatment method for botulism is administration of antitoxin. This treatment is successful only if given very early. Other treatments include artificial respiration, maintaining the fluid balance in the body etc.

The out breaks are caused only when the conditions indicated below are prevalent. (i) Presence of spores of types A, B or E in canned or processed food (ii) A food that can serve as growth media for the organism (iii) Survival of spores of the organism due to inefficient food heating or processing (iv) Suitable conditions of growth and toxin production provided in food (v) Toxin production in food.

These out breaks can be prevented by following certain precautions such as (a) Use of approved heat process for canning (b) Non usage of spoilt cans (c) Avoidance of tasting and also consumption of improperly heated food (d) Boiling of suspected food for more than 15 minutes.

Food infections caused by *Clostridium perfringens (welchii)*
Perfringens Poisoning
This is the poisoning due to the intake of food containing poisoning bacteria. The causative agent is *Clostridium perfringens (welchii)* and was first reported in 1945 in USA. The bacterium is a

Gram-positive, nonmotile, anaerobic, spore-forming rods. Its growth conditions are optimal temperature of 43 to 47^0 C, pH range of 5-9, and a_w of 0.97. The spores of food-poisoning strains differ in their heat resistance. Growth is inhibited by 5% NaCl. The most common foods involved are meat and meat products, poultry and its products, where the heat resistant spores survive and cause infection. The contaminating bacterial organism enters the food at the stage of preparation, and other practices during processing or preservation and increases its population by growth. Foods containing more proteinaceous materials, particularly from animal origin are good substrates for growth of the bacterial contaminant. The anaerobic conditions are created fast in protenaceous foods particularly under covered or packed conditions creating good environment for anaerobic growth of harmful bacilli.

The disease symptoms appear in 8 to 24 hrs after ingestion. They are acute abdominal pain, diarrhoea, gas formation, fever, nausea but vomiting is rare. The symptoms are expressed only on ingestion of millions of viable cells per gram of food. An enterotoxin is released in gut by the injected bacteria during sporulation resulting in excessive fluid accumulation in the intestinal lumen. Fortunately the enterotoxin is heat sensitive and is inactivated at 60^0C for 10 minutes. Out breaks occur when the conditions like contamination of food, development of reduced conditions in food after cooking, inadequate cooling of food, improper reheating of food before consumption etc. The out breaks can be prevented following certain principles like (i) adequate and rapid cooling of cooked meats and other foods, (ii) retention of hot food at 60^0C, (iii) reheating of leftover foods to curb growth of organisms, (iv) maintenance of good personal hygiene.

Food borne disease caused by *Staphylococcus aureus*

Staphylococcal Food Poisoning

Food poisoning is most commonly caused by the ingestion of the enterotoxin formed in food during growth of certain strains of *Staphylococcus aureus*. The toxin is called an enterotoxin as it causes gastroenteritis or inflammation of the lining of the intestinal tract. In case of other enterotoxin poisonings the toxin is commonly produced by bacteria belonging to enterobacteriaceae members.

The organism, *Staphylocussus aureus,* is a typical staphylococcus, showing Gram positive staining reaction and appearing as bunches of cells or like clusters of grapes or in pairs and short chains. Growth on solid media usually is golden or yellow but may be unpigmented in some strains. Most enterotoxin producing *S. aureus* cultures are coagulase positive, produce a thermostable nuclease and are facultative in their oxygen requirements in a complex glucose medium. They grow better aerobically than anaerobic growth. Some of the toxigenic cocci are very salt tolerant and also tolerate nitrites fairly well and therefore can grow in curing solutions and on curing and cured meats if other environmental conditions are favorable. They are fermentative and proteolytic but usually do not produce obnoxious odors in most foods or make them appear unattractive. *S. aureus* produces six serologically distinct enterotoxins that differ in toxicity, but most food poisoning is from type A. The range of conditions permitting growth of the organism and hence toxin production, varies with the food involved. In general, if the food serves as an efficient medium then the coccus can grow at the wider range of temperature, pH or water activity (a_w). The temperature range for growth and toxin production is very wide, about 4 to 46^0 C, depending on the food. The minimal pH for growth is lower under aerobic conditions than under anaerobic, e.g., in meat the minimal pH is 4.8 in aerobic conditions than about 5.5 in anaerobic, while the maximal pH for growth is about pH 8.0. The minimal a_w is about 0.86 under aerobic conditions and about 0.90 under anaerobic conditions. A sub-lethal heat treatment decreases tolerance to salt.

The sources from which the food poisoning staphylococci enter foods are from the most part human or animal. The nasal passages of many persons are laden with these organisms, which are a common cause of sinus infections. Also, boils and infected wounds may serve as other sources of these bacteria. The human skin that harbours these organisms, is a source of these infecting bacteria only when they have come from nasal passages or local infections. Staphylococci are becoming increasingly important in causing mastitis in cows and some of these cocci can form enterotoxin in milk or milk products. Ordinarily, air is a relatively unimportant source of the cocci, except when they are being introduced there from infected human sources.

The staphylococcal enterotoxins are simple proteins. The enterotoxin types A and D are more often associated with food poisoning outbreaks. Fortunately sufficient levels of enterotoxin are produced only after considerable growth of the organism, usually a population of at least several millions per milliliter or gram of food item must be attained for manifestation of food poisoning. Therefore, the conditions that favor toxin production are those best for growth of the *Staphylococcus*. Toxin is produced at an appreciable rate at temperatures between 15.6 and 46.1^0C and production is best at 40^0 C. Under the best conditions, enterotoxin may be produced within 4 to 6 hr. The lower the temperature during growth, the longer it will take to produce enough enterotoxin to cause poisoning. Enterotoxin has been demonstrated in a good culture medium in 3 days at 18^0 C and in 12 hr at 37^0 C but not if temperature is lowered even by two degrees or even altered like no growth in 3 days at 15^0 C, or 7 days at 9^0 C, or 4 weeks at 4 to 6^0 C. Production of enterotoxin by the staphylococci is more likely in heated food when competing microorganisms are absent, few or inhibited, as interference with these microbes is absent. There is evidence that toxin is produced by staphylococci growing in the intestinal tracts of patients when treatment with antibiotics has destroyed or inactivated other competitive bacteria there.

The type of food evidently has an influence on the amount of enterotoxin produced. Little toxin is produced in salmon, for example and much in meat products and custard-filled bakery goods. The presence of starch and protein in considerable amounts is supposed to enhance toxin production by the staphylococci. An important characteristic of the enterotoxins is their stability toward heat, and this is influenced by variation in initial concentration, the medium in which heated and the temperature of heating.

Many kinds of foods have been involved in causing staphylococcal food poisoning. Of these, custard and cream filled bakery goods, ham and poultry have caused the most outbreaks. About 75 percent of all staphylococcal food poisoning outbreaks occur because of inadequate cooling of foods. Other foods incriminated include meats and meat products, fish and fish products, milk and milk products, cream sauces, salads, puddings, custards, pies and salad dressings. The fillings in bakery goods rich in sugars and nutrients usually are good culture media in which the staphylococci can grow during the time that these foods are held at room temperatures. Toxin production has even been reported in imitation cream filling.

Staphylococcal infection or food poisoning differs in its manifestation in different people depending on their susceptibility, so that even if a group of people consume food containing toxin, some may become very ill and a lucky few may be affected little or not at all. The incubation period for this kind of poisoning usually is brief, 2 or 4 hr differing in this respect from the other common food poisonings and infections, which usually have longer incubation periods. The most common human symptoms are salivation, then nausea, vomiting, retching, abdominal cramping of varying severity and diarrhoea. Blood and mucus may be found in stools and vomits in severe cases. Headache, muscular cramping, sweating, chills, prostration, weak pulse, shock and shallow respiration also may be the manifestations. A subnormal body temperature rather than fever is expressed.

The outbreaks of staphylococcus food poisoning generally occur when the following conditions are fulfilled.

- The food must contain enterotoxin producing staphylococci
- The food must be a good culture medium for growth and toxin production by the staphylococci
- The temperature must be favorable to growth of the cocci, and enough time must be allowed for production of enterotoxin
- The enterotoxin containing food must be ingested.

The out breaks can be prevented by preventing contamination of food with the organism, preventing the growth of the organism, proper heating to kill the organism, efficient refrigeration, maintenance of acidic pH in food and by addition of bacteriostatic agents to food.

Food infection caused by *Salmonella*

Salmonellosis is the infection caused by members of the genus *Salmonella*. It is the most frequently occurring bacterial food infection and is caused by ingestion of live bacteria along with food. The infections are caused by a large number of serovars. The organisms are Gram-negative non-spore forming bacilli that are identified by their fermentation of glucose with acid and gas but not lactose or sucrose. The growth conditions span over a range like temperature from 6.7 to 45.6^{0}C, pH from 4.1 to 9, and a_w from 0.93 to 0.95. The species and strains of *Salmonella* differ in heat resistance and in their response to environmental factors of growth. The infectiveness of *Salmonella* depends on the resistance of the consumer, the number of organisms ingested and the species of the organism. Species like *S. pullorum* are less infective and *S. enteritidis* is more infective. *Salmonella* can successfully attain sufficient numbers in foods without detection as they do not alter any of the properties of food like taste odour, etc.

The different species of *Salmonella* causing salmonellosis infection are *S .enteritidis, S. choleraesuis, S. typhimurium, S. infantis* and those causing fevers are *S . typhi, S, paratyphi,* etc. The sources of *Salmonella* infection either directly or indirectly are the human beings and animals that contaminate the food items both as carriers and the diseased. Different animal sources are cats, dogs, swine and cattle, but more important sources are poultry and their eggs.

Majority of *Salmonella* outbreaks are due to the involvement of meat and poultry products. Foods involved are meat products like meat pies, sausages, cured meats, sandwiches, fish, seafood, milk and milk products like ice creams, fermented milk, cheese etc.

The incubation period for Salmonella is longer (12 to 36 hrs) hence can be distinguished from staphylococcal infection as its incubation period is 2 to 4 hr. The main symptoms of salmonellosis are nausea, vomiting, abdominal pain, diarrhoea, headache and chills. Moderate fever, restlessness, watery-greenish foul-smelling stools, muscular weakness are also manifested. The mortality rate is as low as 1% or less. Symptoms persist for short periods like 2 to 3 days followed by recovery.
The conditions necessary for out break are: (i) contamination of food by bacteria, (ii) increased number of bacteria mostly due to growth in food, (iii) favourable growth conditions and (iv) ingestion of viable organisms. The out breaks can be prevented by following certain principles like avoidance of contamination of food with bacteria, destruction of organisms in food by heating, proper storage of food by refrigeration to avoid growth and also following strict hygiene in preparation, processing and storage of foods.

Food borne disease caused by *Bacillus cereus*

Bacillus cereus has been recognized as an agent of food poisoning since 1955. Between 1972 and 1986, 52 outbreaks of food-borne disease associated with *B. cereus* were reported to the Centre for Disease Control (CDC), but this is thought to represent only 2% of the total cases which have occurred at that time. *B. cereus* causes two types of **food-borne intoxications** (as opposed to infections). One type is characterized by nausea and vomiting and abdominal cramps and has an incubation period of 1 to 6 hours. It resembles *Staphylococcus aureus* food poisoning in its symptoms and incubation period. This is the "short-incubation" or **emetic form** of the disease. The second type is manifested primarily by abdominal cramps and diarrhoea with an incubation period of 8 to 16 hours. Diarrhoea may be a small volume or profuse and watery. This type is referred to as the "long-incubation" or **diarrheal form** of the disease and it resembles more food poisoning caused by *Clostridium perfringens.* In either type, the illness usually lasts less than 24 hours after onset. In a few patients symptoms may last longer.

The organism
Bacillus cereus is a Gram-positive, large rods, cells sporulate and germinate easily. It has short generation time (20-30 min), grows in a temperature range of 5-50^{o}C, optimum 35-40^{o}C, pH range 4.5-9.3, high heat and drying resistance of spores, acid from sugar fermentations (except mannitol) and mildly proteolytic in nature.

Bacillus cereus produces extracellular enzymes like, proteases (sweet curdling of dairy products), **β**-lactamases (penicillin resistance), phospholipases, bitty cream defect in milk and cream and hemolysins.

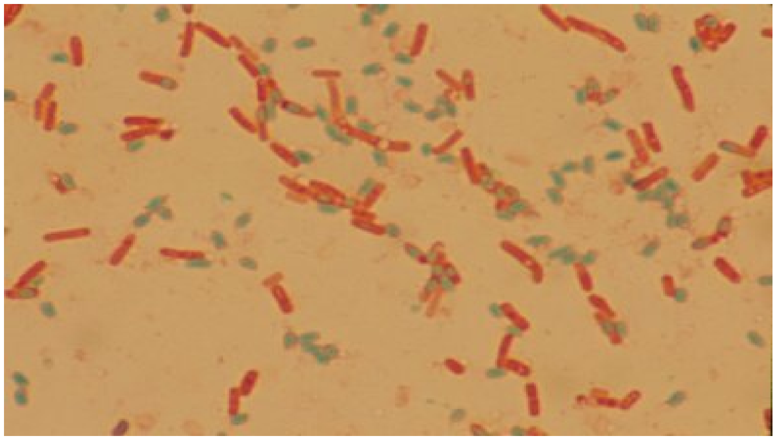


Fig. *Bacillus cereus* spores with green colour stain

Common sources of infection include:

- Raw, dried or processed foods such as cereals, cornflower, spices, and other dried foods.
- The general environment including soil, air, dust, water and decaying matter.
- Animals.
- Foods such as turkey, beef, seafood, salads, potatoes, rice, noodles, food mixes - (sauces, soups and casseroles), milk powder, various bakery products and desserts especially items with custard and cream.
- The emetic toxin type grows well in rice dishes, mashed potatoes, other starchy foods and vegetable sprouts, while the diarrhoeal toxin type grow in a variety of foods from vegetables and salads to meat and casseroles.

Pathogenesis

Infectious dose is high (> 10^5/g). It results with the action of heat stable diarrhoeal toxin. It causes tissue damage and altered permeability in the intestinal mucosa. It is associated with meat or vegetable containing foods after cooking. In a study the bacterium is also isolated from 50% of dried beans and cereals and from 25 % of dried foods such as spices, seasoning mixes and potatoes indicating its wide spread occurrence in food items.

Syndrome by *B. cereus* food poisoning has

- watery diarrhoea, cramps, abdominal pain
- nausea but not vomiting, no fever
- onset 12-18 hr.
- duration less than 24 hr.
- symptoms are similar or equal to *C. perfringens* food poisoning

Early reports of such symptoms are in Europe in early 1900's and linked to food-borne outbreaks in 1950's. The first complete account of outbreaks was given by Hague (Norway) who drank the culture in vanilla sauce and showed the symptoms. It is recognized as food poisoning world wide in 1970s. The food poisonings in USA are reported during 1977 – 1984 in meat loaf cooked rice, mashed potatoes green bean salad, chicken pot pie vanilla sauce, vegetable sprouts turkey loaf.

Emetic (vomiting) food poisoning or short incubation disease has the short-incubation form caused by a pre-formed heat-stable enterotoxin of molecular weight less than 5,000 Daltons. The mechanism and site of action of this toxin are unknown. The syndrome has

- acute nausea and vomiting
- diarrhea not common
- no fever
- onset 1-5 hr.
- duration 6-24 hr.
- symptoms are similar to *S. aureus* food poisoning but counts of **B. cereus** in foods are very high compared to *S. aureus*.

Preventive measures that can be taken to help avoid the illness

- Ensuring adequate temperatures are reached during cooking of food mixes such as sauces, custards, and soups to inactivate the bacteria.
- Keeping cooked hot foods above 60^{o}C (preferably 70^{o}C) if not served immediately.
- Ensuring the rapid cooling of cooked food by dividing into smaller lots and refrigerating in shallow containers (less than 10cm deep).
- Storing cold foods at or below 4^{o}C to prevent toxin being produced.
- Avoiding storing protein-containing foods with cooked rice because this stimulates the growth of *B. cereus*.
- Reheating foods to 75^{o}C or until steaming hot, as flash frying or brief re-warming is not adequate to destroy the toxin.
- Preventing cross-contamination from raw to cooked foods (by using separate preparation areas or sanitizing between processes).
- Thoroughly washing fruit and vegetables with clean water of drinking standard before use.
- Ensuring food handlers have good personal hygiene and adequate food safety training.

Food borne disease caused by *Listeria monocytogenes*

Listeria monocytogenes is a Gram-positive rod-shaped bacterium. It is the agent of **listeriosis**, a serious infection caused by eating food contaminated with the bacteria. Listeriosis has recently been recognized as an important public health problem in the United States. The disease affects primarily pregnant women, newborns, and adults with weakened immune systems. The *overt form* of the disease has mortality greater than 25 percent. The two main clinical manifestations are sepsis and meningitis. Meningitis is often complicated by encephalitis, a pathology that is unusual for bacterial infections.

Microscopically *Listeria* species appear as small, Gram-positive rods, which are sometimes arranged in short chains. In direct smears they may be coccoid, some times they may be mistaken for streptococci. Longer cells may resemble corynebacteria. Flagella are produced at room temperature but not at 37° C. Hemolytic activity on blood agar has been used as a marker to distinguish *Listeria monocytogenes* among other Listeria species, but it is not an absolutely definitive criterion. Further biochemical characterization may be necessary to distinguish between the different *Listeria* species.

In humans, overt listeriosis following infection with *L. monocytogenes is* usually sporadic, but outbreaks of epidemic proportions have occurred. In 1981, there was an outbreak that involved over 100 people in Canada. Thirty-four of the infections occurred in pregnant women, among whom there were nine stillbirths, 23 infants born infected, and two live healthy births. Among 77 non-pregnant adults who developed overt disease, there was nearly 30% mortality. The source of the outbreak was coleslaw produced by a local manufacturer.

In 1985, in California, 142 people developed overt listeriosis. Of these, 93 cases were perinatal, and among the 49 cases that were in non pregnant individuals, 48 were immuno compromised. Thirty fetuses or newborn infants died and 18 adults died. The source of the bacteria was a certain brand of "pasteurized" soft cheese that apparently had got contaminated with non pasteurized (raw) milk during the manufacturing process.

Listeria monocytogenes is found in soil and water. Vegetables can become contaminated from the soil or from manure used as fertilizer. Animals can carry the bacterium without appearing ill and can contaminate foods of animal origin such as meats and dairy products. The bacterium has been found in a variety of raw foods, such as uncooked meats and vegetables, as well as in processed foods that become contaminated after processing, such as soft cheeses and cold cuts at the deli counter. Un-pasteurized (raw) milk or foods made from un-pasteurized milk may contain the bacterium.

Listeria is killed by pasteurization and cooking; however, in certain ready-to-eat foods such as hot dogs and deli meats, contamination may occur after cooking but before packaging.

Pathogenesis

Listeria monocytogenes is presumably ingested with raw, contaminated food. An invasion secreted by the pathogenic bacteria enables the listeriae to penetrate epithelial lining of the host cells. The bacterium is widely distributed and this event may occur frequently. Normally, the immune system eliminates the infection before it spreads. Adults with no history of listeriosis have T lymphocytes primed specifically by L*isteria* antigens. However, if the immune system is compromised, systemic disease may develop. *Listeria monocytogenes* multiplies not only extracellularly but also intracellularly, within macrophages after phagocytosis, or within parenchymal cells which are entered by induced phagocytosis.

It is believed that ingestion of as few as 1,000 cells of Listeria bacteria can result in illness. After ingestion of food contaminated with Listeria, incubation periods for infection are in the range of 3 to 70 days, usually 4 to 21 days. Five days to three weeks after ingestion, Listeria has access to all body areas and may involve the central nervous system, heart, eyes, or other locations. Fetuses of pregnant women are particularly vulnerable to the Listeria infection.

A person with listeriosis usually has fever, muscle aches, and gastrointestinal symptoms such as nausea or diarrhea. If infection spreads to the nervous system, symptoms such as headache, stiff neck, loss of balance, confusion, obtundation or convulsions can occur. With brain involvement, listeriosis may mimic a stroke. Infected pregnant women generally experience only a mild, flu-like illness; however, infection during pregnancy can lead to miscarriage, infection of the newborn, or even stillbirth. The prenatal and neonatal mortality rate is about 80%.

Human cases of Listeria are, for the most part, sporadic and treatable. Nonetheless, listeriosis remains an important threat to public health, especially among those most susceptible to this disease. With the increase of the numbers of immunocompromised people, the risk multiplies. The fact that listeriosis is a disease easily transmitted from mother to fetus through the placenta is worrisome to an expectant mother, especially since pregnant women themselves rarely show outward signs of such a devastating infection.

Preventing Listeriosis

Although there are no vaccines against the bacteria that cause listeriosis, you can help reduce the risk for yourself and your family by taking certain food safety precautions:

- Always cook food (especially meat and eggs) thoroughly to the proper internal temperature.
- Wash fruits and vegetables thoroughly before eating.
- Only drink pasteurized milk, and make sure that milk is refrigerated at the appropriate temperature, which is less than 40^0F (4^0C).
- Avoid foods made from un-pasteurized milk.
- If you are in a high-risk group, avoid soft cheeses such as Feta, Brie, Camembert, blue-veined and Mexican-style cheeses unless they have labels that clearly state they are made from pasteurized milk.
- Reheat precooked, prepackaged foods - such as deli meats or hot dogs - to steaming hot temperatures, especially if you're pregnant

Food borne diseases caused by *Vibrio parahaemolyticus*

Vibrio parahaemolyticus is a naturally occurring organism commonly found in waters where oysters are cultivated. It is Gram negative comma shaped bacterium. When the appropriate conditions occur with regard to salt content and temperature, *V. parahaemolyticus* thrives. A marine vibrio is normally associated with food poisonings involving seafood consumption. It is a major cause of food poisoning in Asian countries. Certain strains (Kanagawa phenomenon-positive, KP+) are primarily involved with human disease.

The organism grows in the temperature range 5-43^0C, with optimum at 37^0C. Growth is very rapid under optimum conditions. pH range 4.8-11 with optimum at 7.8-8.6. Minimum pH for growth decreases as the incubation temperature increases towards the optimum. Growth is inhibited in the presence of 0.1% acetic acid (pH 5.1). The bacterium can grow in the presence or absence of oxygen, but grows optimally under aerobic conditions.

The Illness

The disease has incubation period of 4-74 hours after infection. Symptoms include, abdominal cramps and watery diarrhoea, sometimes nausea, vomiting and fever. Symptoms last from 1 to 7 days, occasionally may continue for longer time. Mean duration is 2.5 days. Hospitalization is required in approximately 7% of cases. The disease is usually self-limiting. Extra intestinal infections can occur.

The disease is a primarily gastrointestinal infection. The KP+ factor is a haemolysin. Expression of this haemolysin seems to be responsible for the symptoms. However other virulence factors, such as a shiga-like toxin are also likely to be involved. Long term effect is reactive arthritis has been reported. Ingestion of 2×10^5 - 3×10^7 cells is required to cause disease in healthy adults, but it may be lower in the presence of antacids or food.

Foods of marine origin may harbour this organism. Levels may approach 10^3/g in fresh seafood and may be greater in the warmer months. Large proportions (60-100%) of seafood samples in the USA were found to contain the organism. Seafoods are the food group most often associated with outbreaks.

Preventive measures
Cook shellfish (oysters, clams, mussels) thoroughly. For shellfish in the shell, either boil until the shells open and continue boiling for five more minutes, or steam until the shells open and continue cooking for nine minutes. For shucked oysters, boil for at least three minutes or fry them in oil at least 10 minutes at 350^oC. Do not eat shellfish that do not open during cooking. Do not allow seafood already cooked to touch raw seafood, and do not touch cooked seafood after you have handled raw seafood without washing your hands first.

Certain health conditions put at risk for serious illness or death if persons affected become sick from eating contaminated raw seafood. People with the following health conditions should not eat seafood that is uncooked:

- liver disease, either from excessive alcohol intake, viral hepatitis or other causes
- hemochromatosis, an iron deficiency disorder
- diabetes
- stomach problems, including previous stomach surgery and low stomach acid
- cancer
- immune disorders, including HIV infection
- long-term steroid use (as for asthma and arthritis).

Food borne diseases caused by Camphylobacter jejun*i*

Camphylobacter jejuni is a slender, spirally curved rod with a single polar flagellum at one or both ends of the cell. It is oxidase and catalase positive and will not grow in the presence of 3.5% NaCl or at 25^0C. It is microaerophilic, requires small amounts of oxygen (3 – 6%) for growth. It is the most important pathogen in causing diarrhea in humans The organism is heat sensitive at above 55^0C and also sensitive to freezing at below -18^0C. The pathogen is generally present in meat and poultry as contaminant and causes diarrhea on consumption. Large number of major meat animals have been shown to contain these organisms in their feces and in poultry it is more prominent. Excreta of animals and chicken is the major source of contamination by *Camphylobacter jejuni*.

The Illness
Camphylobacter jejuni is the single most common cause of acute bacterial diarrhea in humans in the age group of 10 – 30 years. The disease is more prevalent in summer months. Some strains of *C. jejuni* product heat-labile enterotoxin called as CJT that has some common properties with the enterotoxins of *Vibrio cholerae* and *E.coli*. CJT increases cAMP levels, induces fluid accumulation in intestines resulting in acute diarrhea. The other symptoms include abdominal pain or cramps, malaise, headache and fever which last from 1 – 4 days. In more severe cases, bloody stools may occur, the diarrhea may resemble ulcerative colitis and the abdominal pain may mimic acute appendicitis. The incubation period may vary usually from 48 to 82 hrs but in come times it may be upto 10 days or more. Diarrhea may last 2 to 7 days, and the organisms

may be shed in stool for more than 2 months after symptoms subside. Such persons are the carriers for spread of the disease.

Preventive measures

The pathogen is heat sensitive and are destroyed in contaminated foods and milk by heating above pasteurization temperatures. The infection by this pathogen can be avoided by not eating undercooked or unpasteurized foods of animal origin. Good hygienic living and maintaining sanitary conditions can prevent spread of the disease. It is more important to maintain hygiene of women handling food at home to prevent food contamination by *C. jejuni*.

Diseases caused by *Aeromonas hydrophyla*

Aeromonas hydrophyla is an aquatic bacterium found more in salt waters than in fresh waters. The pathogen is a Gram negative rod and positive for Voges-Proskauer and hemolysin tests. The organism grows at 0-20^{0}C and has optimum between 15-20^{0}C. Some strains give maximum growth even at 35^{0}C. It is aerobic, heterotrophic and halophilic with growth at 15% salt concentration. It is a significant pathogen to fish, turtles, frogs, snails and alligators. It is a human pathogen in compromised hosts. It is a common member of bacterial flora of pigs. Diarrhea, endocarditis, meningitis, soft tissue infections and bacteremia are caused by *A. hydrophila*. Virulent *A. hydrophila* produces polypeptide enterotoxin which is cytotoxic and hemolytic. The toxin has cross reactivity with cholera toxin. People eating unhygienic pork, fish, turtles, frogs, etc. are prone to get infection and diarrhea caused by *A. hydrophila*. The infection by this pathogen can be prevented with good hygienic living and cooked food habits.

Diseases caused by *Mycobacterium paratuberculosis*

Mycobacterium paratuberculosis is an obligate pathogen. It is known to cause disease in a wide variety of animals, including primates and humans. Similar to other obligate pathogens, the environment required by *M. paratuberculosis* for multiplying is the environment found inside mammals and other animals. In animals, the most common site for infection by this pathogen is the gastrointestinal tract, where it tends to cause a chronic inflammatory disease. The most well studied animal paratuberculosis is Bovine Johne's Disease (BJD), the name given because of the disease seen in cattle. The disease is spread through contaminated foods particularly milk from animal to animal and animal to man. The pathogen occurs in two forms, the bacillary form and the spheroplast form. Many paratuberculosis bacteria of the bacillary form may be required to cause clinical disease. In contrast, only a few paratuberculosis bacteria of the spheroplast form will cause disease. This diference between disease caused by the two forms is a result of the infected hosts immune system.

The illness

M. paratuberculosis is endemic in foods derived from cattle in most areas of the western world. The pathogen is present in milk, faeces and meat of infected cattle. There evidence that *M. paratuberculosis* is not killed by standard food processing techniques such as pasteurization. It is now proved that *M. paratuberculosis* causes important disease called Crohn's disease. Crohn's disease is an ongoing disorder that causes inflammation of the digestive tract or gastrointestinal (GI) tract. Crohn's disease can affect any area of the GI tract, from the mouth to the anus, but it

most commonly affects the lower part of the small intestine, called the ileum. The swelling extends deep into the lining of the affected organ. The swelling can cause pain and can make the intestines empty frequently, resulting in diarrhea. The disease affects man and women equally.
The disease caused by *M. paratuberculosis* are prevented by hygienic living and maintaining good sanitary conditions in dairy industry. Health of milk animals is important to prevent the disease. Also milk handlers are important source of spread of this pathogen. Good hygiene needs to be maintained in milk handlers to prevent the contamination of this pathogen in milk. Treatment includes drugs, nutrition supplements, surgery, or a combination of these options. The goals of treatment are to control inflammation, correct nutritional deficiencies, and relieve symptoms like abdominal pain, diarrhea, and rectal bleeding. At this time, treatment can help control the disease by lowering the number of times a person experiences a recurrence, but there is no cure. Treatment for Crohn's disease depends on the location and severity of disease, complications, and the person's response to previous medical treatments when treated for reoccurring symptoms.

Mycotoxins

Mycotoxins are poisonous chemical compounds produced by certain fungi. There are many such compounds, but only a few of them are regularly found in food and animal feedstuffs such as grains and seeds. Nevertheless, those that do occur in food have great significance in the health of humans and livestock. Since they are produced by fungi, mycotoxins are associated with diseased or mouldy crops, although the visible mould contamination can be superficial.

Food borne mycotoxins

There are five mycotoxins, or groups of mycotoxins, that occur quite often in foods. They are, deoxynivalenol/nivalenol, zearalenone, ochratoxin, fumonisins, and aflatoxins.

The food-borne mycotoxins likely to be of greatest significance for human health in tropical developing countries are the fumonisins and aflatoxins. Fumonisins were discovered as recently as 1988, and there is little information on their toxicology.

There is sufficient evidence in experimental animals for the carcinogenicity of cultures of *Fusarium moniliforme* that contain significant amounts of fumonisins and there is limited evidence in experimental animals for the carcinogenicity of fumonisin B1. *F. moniliforme* growing in maize may produce fumonisin B1, a suspected human carcinogen. Also, fumonisin B1 is toxic to pigs and poultry, and is the cause of equine leucoencephalomalacia (ELEM), a fatal disease of horses.

Fumonisins have been found as a very common contaminants of maize-based foods and feeds in Africa, China, France, Indonesia, Italy, the Philippines, South America, Thailand, and the USA. Strains of *F. moniliforme* isolated from sorghum are considered to be poor producers of fumonisins.

Disease	Etiologic agent	Incubation period, signs and symptoms	Foods involved	Control measures
Vibrio parahaemolyticus infection	***V.parahaemolyticus***	2-48 hr, usually 12 hr; abdominal pain, diarrhoea, usually nausea and vomiting, mild fever, chills, headache, prostration; recovery within 2-5 days	Raw foods of marine origin; saltwater fish, shellfish, crustacean and fish products	Cook foods thoroughly; chill foods rapidly in small quantities; prevent cross contamination from saltwater fish; sanitize equipment; avoid use of seawater for rinsing foods to be eaten raw.
Enteropathogenic *Escherichia coli* infection	*E.coli*; both enterotoxigenic and invasive strains cause illness	8-44 hr, invasive illness; fever, chills, headache, myalgia, abdominal cramps, profuse, watery diarrhea; enterotoxigenic illness; diarrhea, vomiting, dehydration, shock; similar to cholera	Coffee substitute, salmon, cheese	Chill foods rapidly in small quantities; cook foods thoroughly; practice personal hygiene; prepare foods in sanitary manner; protect and treat water; dispose of sewage in sanitary manner.
Bacillus cereus gastroenteritis	Diarrheal, syndrome, diarrheagenic toxin	8-16 hr or 1.5-5 hr; nausea, abdominal cramps, watery diarrhoea, some vomiting	Custards, cereal products, puddings, sauces, meat loaf	Chill foods rapidly in small quantities; hold hot foods at 65^0 C or above; practice personal hygiene; process and prepare food in sanitary manner; reheat leftover foods to 71.1C
Yersiniosis	*Yersinia pseudotuberculosis, Y enterocolitica*	24-36 hr and longer; abdominal pain like in acute appendicitis, fever, headache, malaise, anorexia, diarrhoea, vomiting, nausea, chills, pharyngitis, leukocytosis, erytherma nodosum	Pork and other meats, raw milk, or nay contaminated raw or leftover food	Cook foods thoroughly; protect foods from contamination; control rodents
Beta-hemolytic Streptococcal infections	*Streptococcus pyogenes*	1-3 days; sore and red throat, pain in swallowing, tonsillitis, high fever, headache, nausea, vomiting, malaise, rhinorrhea; occasionally a rash occurs	Milk,icecream, eggs, steamed lobster, potato and egg salad, custard and pudding; foods usually contain eggs or milk	Chill foods rapidly in small quantities; practice personal hygiene; cook foods thoroughly; pasteurize milk, exclude workers with respiratory illness or skin lesions

Table 1: Characteristics of some food borne illnesses

Aflatoxins were discovered over 30 years ago and have been subject to a great deal of research. They are potent human carcinogens and interfere with the functioning of the immune system. Among livestock, they are particularly toxic to chickens. In 1993, the International Agency for Research on Cancer (IARC) assessed and classified naturally occurring mixtures of aflatoxins as class 1 human carcinogens. Aflatoxins B1, B2, G1, and G2 have been found to occur in commodities in America and Africa, and have been detected in human sera. IARC has concluded that aflatoxin B1 is a class 1 human carcinogen. Residues of aflatoxin B and/or its metabolite, aflatoxin M, can occur in animal products, including milk. Aflatoxin M, is also found in human milk if the mother consumes food containing aflatoxin B1. IARC has given aflatoxin M, a lower carcinogenicity rating than aflatoxin B1. It is clear that exposure to aflatoxins is hazardous to human health. For that reason, most countries have regulations governing the allowable concentrations of aflatoxin in foods and feeds.

Aflatoxin B, the most toxic of the aflatoxins, causes a variety of adverse effects in different domestic animals. Effects on chickens include liver damage, impaired productivity and reproductive efficiency, decreased egg production in hens, inferior egg-shell quality, inferior carcass quality and, most important from a human perspective, increased susceptibility to disease.

Fungal ecology and mycotoxin production in foods

The fungi that produce mycotoxins in food fall broadly into two groups: those that invade before harvest, commonly called field fungi, and those that occur only after harvest, called storage fungi. There are three types of toxicogenic field fungi: plant pathogens such as *F. graminearum* (produces deoxynivalenol, nivalenol); fungi that grow on senescent or stressed plants, such as *F. moniliforme* (produces fumonisin) and sometimes *A. flavus* (produces aflatoxin), and fungi that initially colonise the plant before harvest and predispose the commodity to mycotoxin contamination after harvest, such as *P. verrucosum* (produces ochratoxin) and *A. flavus (produces* aflatoxin).

In all these cases there is a more or less well-defined association between the fungus and its plant host. *Aspergillus* and *Fusarium* species are likely to be the most significant mycotoxin-producing field fungi found in tropical developing countries.

Mouldy, damaged peanuts are found to be containing high levels of aflatoxins. Aflatoxins in this commodity have frequently been found in parts of South-East Asia - a result of poor handling and storage practices. Fusarium kernel rot is one of the most important ear diseases of maize in hot growing areas. It is associated with warm, dry years and/or insect damage. There is a strong relationship between insect damage and fusarium kernel rot. It has been found during field survey work, for example, that the incidence of the European corn borer increased *F. moniliforme* disease and fumonisin concentrations.

Temperature stress of the growing plant is also important. Studies of fumonisin occurrence in maize hybrids grown across the U.S. Corn Belt and in Europe and Africa indicate that hybrids grown outside their range of temperature adaptation have higher fumonisin concentrations.

After harvest, when grains or seeds have become moribund or dormant as a result of drying, associations between fungi and plants disappear, and physical factors dictate whether or not members of the other group, the storage fungi, will grow and/or produce mycotoxins. The primary factors influencing fungal growth in stored food products are the moisture content (more precisely, the water activity) and the temperature of the commodity. In practice in the tropics, the temperature is almost always suitable for storage fungi, so it is the water activity that becomes the prime determinant of fungal invasion and growth.

Control of mycotoxins production

It is required to prevent and control mycoxins production in stored grains and seeds. Fungi cannot grow (or mycotoxins be produced) in properly dried foods. Therefore efficient drying of food commodities and maintenance of the dry state is an effective control measure against fungal growth and mycotoxin production.

To reduce or prevent production of most mycotoxins, drying should take place soon after harvest and as rapidly as feasible. The critical water content for safe storage corresponds to a water activity (a_w) of about 0.7. Maintenance of foods below 0.7 a_w is an effective technique used throughout the world for controlling fungal spoilage and mycotoxin production in foods.

Problems in maintaining an adequately low a_w often occur in the tropics, where high ambient humidities make control of commodity moisture difficult. The grain is held in bags, systems that employ careful drying and subsequent storage in moisture-proof plastic sheeting may overcome this problem.

While it is possible to control fungal growth in stored commodities by controlled atmospheres or use of preservatives or natural inhibitors, such techniques are almost always more expensive than effective drying, and are thus rarely feasible in developing countries.

Damaged grain is more prone to fungal invasion and therefore mycotoxin contamination. It is thus important to avoid damage before and during drying, and in storage. Drying of maize on the cob, before shelling, is a very good practice to prevent fungal growth and mycotoxin production.

Indices of Food Sanitation

Microbiological quality of foods depends on the type and quantity of microflora present in them. Microorganisms associated with foods may be pathogenic and non pathogenic. It is expected that foods do not contain pathogenic microorganisms. There are certain microorganisms which are non pathogenic but associated with pathogenic microorganisms in terms of their ecological origin. Therefore presence of such non pathogenic microorganisms indicates possible presence of pathogenic microorganisms and their risk to the consumer. The generally tested indicator organism is *Escherichia coli* which represents the coliform bacteria present in colon of man and animals. Generally such indicator organisms are employed to reflect the microbiological quality of foods relative to product shelf life or their safety from food borne pathogens. Such indicators are most often used to assess food sanitation and its microbiological quality.

Indicators of Food Product Quality

The indicators of microbial quality or shelf-life are the organisms or their metabolic products in foods at certain levels may be used to assess existing quality or to predict product shelf life. The indicator organisms should meet the following criteria:

1. They should be present and detectable in all foods whose quality is to be assessed
2. Their growth and numbers should have a direct negative correlation with product quality
3. They should be easily detected and enumerated and be clearly distinguishable from other organisms
4. They should be enumerable in a short period of time, ideally within a working day
5. Their growth should not be affected adversely by other components of the food flora.

Generally the most reliable indicators of product quality tend to be product specific. Because, a given indicator organism may not be expected to be present in all foods as type of microflora associated with a given food depends on its composition, source, processing conditions etc. Some of the indicator organisms associated with foods for their quality are given in table below. These may not be exclusive indicators but may be found as dominant microflora associated with such foods. The spoilage is the result of growth of a single organism or more than one organism. The overall quality of products is a function of the number of organisms present and shelf life can be increased by their control. As a result, microbiological quality indicators are spoilage organisms whose increasing numbers result in loss of product quality.

Food product	Indicator organism
Fruit juice concentrates	Yeasts
Raw milk (Chilled)	*Lactococcus lactis*, Psychrotrophs
Beer and wine	Lactic acid bacteria
Canned vegetables	Spores of bacteria
Bread dough	*Bacillus* spp.
Cider	*Acetobacter* spp.

Table 2: Food quality indicator organisms of some foods

Some times the microbial metabolic products may be used to assess the product quality. The diamines, histamine, polyamines have been found to be of value for several products as indicator metabolic products. Diacetyl is the best negative predictor of quality in frozen orange juice concentrates, where it imparts a buttermilk aroma. Ethanol is the most predictive of several alcohols in fish extracts stored at low temperatures. Lactic acid is the most frequently found organic acid in spoiled canned vegetables. Production of trimethylamine (TMA) from trimethyl-N-oxide by fish spoilers is used as indication or spoilage index.

Total viable count methods have been used to assess product quality in terms of microbial numbers. These are of greater value as indicators of the existing state of given products than as predictors of shelf life since the portion of the count represented by the ultimate spoilers is difficult to ascertain. Overall, microbial quality indicator organisms or their metabolic products can be used for food products in quality assessment.

Indicators of Food Safety

Foods are likely to have a variety of microorganisms associated with them. Though most of microbes associated with foods may not be harmful, some of them may be harmful which affect the health of consumers. It is necessary to control the microbial numbers in foods to preserve the quality and prevent food borne diseases. Microbial indicators are more often employed to assess food safety and sanitation than quality. The food safety indicator organisms should meet certain important criteria which include:

1. The microorganisms present must be easily and rapidly detectable.
2. They must be easily distinguishable from other members of the food flora.
3. Have history of constant association with the pathogen whose presence indicates the risk of disease.
4. The indicator be present when the pathogen of concern is present.
5. The numbers of indicator organism ideally correlate with those of the pathogen of concern.
6. The indicator organisms growth requirements and growth rate should equal with that of the pathogen.
7. The die-off rate of indicator should be equal to that of pathogen and should persist longer periods than the pathogen.
8. Such indicator organisms must be absent in foods to be safe.

Such indicator criteria apply to most of the foods that may be vehicles of food borne pathogens irrespective of their source to the foods. The safety indicators, however, certain pathogens are assumed to be of intestinal origin, resulting from either direct or indirect fecal contamination. Thus such sanitary indicators are used historically to detect fecal contamination of waters and thereby the possible presence of intestinal pathogens. The first fecal indicator was *Escherichia coli*. Some of the other indicators of fecal pollution are:

a) Coliforms
b) Enterococci
c) Bifidobacteria
d) Coliphages

Presence of these groups in foods or water or any other food materials indicates contamination of fecal material in different ways.

Hazard Analysis and Critical Control Points (HACCP)

Microbiological safety is important among the desirable qualities that should be associated with foods. Foods should be free from infectious microorganisms. It may not be possible to prepare foods free from any microorganism though prepared under good manufacturing practices (GMP). However, production of foods with lowest possible microbial number is desirable in any manufacture. Most of the microbial quality control methods involve the quality of raw materials and finished products. However, it is monitored for safe food products preparation at various points of manufacture to control the contaminating microorganisms. Such monitoring results in preparation of quality foods. The development and use of certain rapid methods have been of value but these alone have not obviated the need for newer approaches to ensuring safe foods. The Hazard Analysis Critical Control Point (HACCP) system is the method of choice for ensuring the safety of foods from farm to home. When necessary, microbiological criteria may be established for some ingredients and foods, and these in connection with sampling plans are presented as components of the HACCP system. The HACCP concept was proposed by H.E. Bauman and other scientists in 1971 in USA. Initially it was applied to low acid foods and subsequently the concept is applied throughout the food industry to a large variety of products and the food service industry. The importance of this concept is to assess and control the food infection and food borne diseases. Detailed report on its use is published by the International Commission on Microbiological Specifications for Foods (ICMSF).

HACCP is a system that leads to the production of microbiologically safe foods by analyzing for the hazards of raw materials, those that may appear throughout processing and those that may occur from consumer abuse. While some classical approaches to food safety rely heavily on end product testing, the HACCP system places emphasis on the quality of all ingredients and all processing steps on the premise that safe products will result if these are properly controlled. The system is designed to control organisms at the point of production and preparation. The important five leading factors that contribute for outbreak of food born illness are taken into consideration. These are improper cooling, lapse of more time (more that 12 hrs) between preparation and eating of food, food contamination by handlers, raw ingredients added without subsequent heating/cooking and inadequate cooking/canning/heating of foods. The events associated with handling and preparation of foods are important in food safety. Mishandling of foods in food service sector involves most of the food borne incidents. Proper implementation of HACCP in food service establishments and at home will drastically reduce the food borne illnesses. A subcommittee of the U.S. National Research Council, National Academy of Sciences made the following recommendations in 1985.

“Because the application of the HACCP system provides for the most specific and critical approach to the control of microbiological hazards presented by foods, use of this system should be required of industry. Accordingly, this subcommittee believes that government agencies responsible for control of microbiological hazards in foods should promulgate appropriate regulations that would require industry to utilize the HACCP system in their food protection programs”.

The HACCP system has been endorsed by U.S.A. and several other developed and developing countries. Some of the definitions and concepts are valuable in the development and execution of a HACCP system and these are given below.

Control point: Any point in a specific food system where loss of control can lead to an unacceptable health risk.

Critical control point (CCP): Any point or procedure in a food system where control can be exercised and a hazard can be minimized or prevented.

Critical limit: One or more prescribed tolerances that must be met to ensure that a CCP effectively controls a microbiological health hazard.

Deviation: Failure to meet a required critical limit for a CCP.

HACCP: The written document that delineates the formal procedures to be followed in accordance with these general principles.

Hazard: Any biological, chemical, or physical property that may cause an unacceptable consumer health risk (unacceptable contamination, toxin levels, growth, and/or survival of undesirable organisms).

Monitoring: A planned sequence of observations or measurements of critical limits designed to produce an accurate record and intended to ensure that the critical limit maintains product safety.

Risk category: One of six categories prioritizing risk based on food hazards.

Verification: Methods, procedures, and tests instituted to determine if the HACCP system is in compliance with HACCP plan.

HACCP Principles

The HACCP has the following seven principles:

1. Assess the hazards and risks associated with the growing, harvesting, raw materials, ingredients, processing, manufacturing, distribution, marketing, preparation, and consumption of the food in question.
2. Determine the CCP(s) required to control the identified hazards.
3. Establish the critical limits that must be met at each identified CCP.
4. Establish procedures to monitor the CCP(s).
5. Establish corrective actions to be taken when there is a deviation identified by monitoring a given CCP.
6. Establish effective record keeping systems that document the HACCP plan.
7. Establish procedures for verification that the HACCP system working correctly.

Each principle is explained briefly below:

Assess hazards and risks

Hazards and risks may be assessed for individual food ingredients from the flow diagram or by ranking the finished food product by assigning to it a hazard rating from A through F. A plus sign (+) is assigned when a hazard exists. Six hazard categories have been defined by National Advisory Committee on Microbiological Criteria for Foods (NACMCF), representing an expansion of the three proposed by the National Research Council (NRC) for salmonellae control.

A) A special class of foods that consist of nonsterile products designated and intended for consumption by individuals at risk, including infants, the aged, infirmed, and immuno-incompetents.
B) Product contains 'sensitive' ingredients relative to microbiological hazards (eg. Milk, fresh meats).
C) There is no controlled processing step (such as heat pasteurization) that effectively destroys harmful microorganisms.
D) The product is subject to recontamination after processing but before packaging (eg. Pasteurized in bulk and then packaged separately).
E) Substantial potential for abusive handling exists in distribution and/or by consumers that could render the product harmful when consumed (eg. Products to be refrigerated are held above refrigerator temperatures).
F) There is no terminal heat process after packaging or when cooked in the home.

The formulated product should be assigned to one of the six categories, as defined by the NACMCF from four suggested by the NRC.

Category VI) A special category that applies to non-sterile products designated and intended for individuals in hazard category A.

Category V) Food products subject to all five general hazard characteristics (A, B, C, D, E and F).

Category IV) Food products subject to any four general hazard characteristics.

Category III) Products subject to any three of the general hazard characteristics.

Category II) Products subject to any two general hazard characteristics.

Category I) Products subject to any one of the general hazard characteristics

Category 0) Products subject to no hazards.

Determine critical control points CCP(s)

Two types of CCPs are recognized by ICMSF. CCP1 is to ensure control of a hazard and CCP2 is to minimize a hazard. Typical CCPs are as given below:

- Heat process steps where time-temperature relations must be maintained to destroy given pathogens
- Freezing and time to freezing before pathogens can multiply.
- The maintenance of pH of a food product at a level that prevents growth of pathogens.
- Employee hygiene.

Establish critical limits

A critical limit is one or more prescribed tolerances that must be met to ensure that a CCP effectively controls a microbiological hazard. This could mean keeping refrigeration temperatures within a certain specific and narrow range maintained long enough to effect pathogen destruction.

Establish procedure to monitor CCPs

Monitoring of a CCP involves the scheduled testing or observation of a CCP and its limits; monitoring results must be documented. If, for example, the temperature for a certain process step should not exceed 40^0C, a chart recorder my be installed. Microbial counts generally are not satisfactory at this point since too much time is required for results. Physical and chemical parameters such as time, pH, temperature and a_w can be tested and results obtained immediately.

Establish corrective actions to be taken when deviations occur in CCP monitoring

The action taken must eliminate the hazard that was created by deviation from the plan. If a product is involved that may be unsafe as a result of the deviation, it must be disposed of. While the actions taken may vary widely, in general they must be shown to bring the CCP under control.

Establish effective record keeping to document the HACCP plan

The HACCP plan must be on file at the food establishment and must be made available to official inspectors upon request. Forms for recording and documenting the system may be developed, or standard forms may be used with necessary modifications. Typically, these may be forms that are completed on a regular basis and filed away. The forms should provide documentation for all ingredients, processing steps, packaging, storage and distribution.

Establish procedures for verification that the HACCP system is working correctly

Verification consists of methods, procedures and tests used to determine that the system is in compliance with the plan. Verification confirms that all hazards were identified in the HACCP plan when it was developed, and verification measures may include compliance with a set of established microbiological criteria when established. Verification activities include the establishment of verification inspection schedules, including review of the HACCP plan, CCP records, deviations, random sample collection and analysis and records of verification inspections. Verification inspection reports should include the designation of persons responsible for administering and updating the HACCP plan, dire calibrated, and deviation procedures employed.

Limitations of HACCP

Although HACCP is the best system yet devised for controlling microbial hazards in foods from the farm to the table, the uniform application of HACCP in the food manufacturing and service industries will not be without some debate. Among the lingering questions and concerns raised are the following:

- HACCP requires the education of nonprofessional food handlers, especially in the food service industry and in homes; whether this will be achieved remains to be seen. The failure of these individuals to get a proper understanding of HACCP could lead to its failure.
- To be effective, this concept must be accepted not only by food processors but by food inspectors and the public. Its effective application at any level can be detrimental to its overall access for a product.
- It is anticipated that experts will differ as to whether a given step is a CCP and how best to monitor such steps. This has the potential of eroding the confidence of others in HACCP.
- The adoption of HACCP by the industry has the potential of giving false assurance to consumers that a product is safe, and therefore, there is no need to exercise the usual precautions between the purchase and consumption of a product. Consumers need to be informed that most outbreaks of food borne diseases are caused by errors in food handling in homes and food service establishments and that no matter what steps a processor takes, HACCP principles must be observed after foods are purchased for consumption.

Prevention of Food Adulteration (PFA)

Food is one of the essentials of life. So it should be pure, nutritious and free from any type of adulteration for proper maintenance of human health. It is the duty of every Government to make pure food available to the countrymen in sufficient quantities. In order to make available unadulterated food in the country, the Government makes various food laws. Similarly, Government of India also made the laws to prevent adulteration in food articles in 1954 called "Prevention of Food Adulteration Act, 1954". To given effect to the provisions of the Act, Rules were made in 1955 and called "Prevention of Food Adulteration Rules, 1955". Though PFA Act and Rules are Central Legislature but the responsibility of implementation has been entrusted to the State Governments and Union Territories. Each State Government and Union Territory has created its own organisation for implementation of the Act and Rules framed thereunder.

Till 1976 in Delhi, the Prevention of Food Adulteration Act and Rules were implemented by Municipal Corporation of Delhi, NDMC and Delhi Cantt. Board in their respective areas through Sanitary Inspectors notified as Food Inspectors. In 1976 major amendments were made in PFA Act and Rules, the implementation work of the Act and Rules made thereunder were taken over by the Govt. of Delhi by the Directorate of Health Services. Later on separate Directorate of Prevention of Food Adulteration were created and entrusted the responsibility of implementation of the provisions of PFA Act and Rules. The Directorate is headed by the Director, an IAS officer and notified to function as Food Health Authority under the Act.

Bureau of Indian Standards (BIS)

The **product certification scheme of BIS** aims at providing Third Party Guarantee of quality, safety and dependability of products to the ultimate customer. Presence of ISI certification mark known as **Standard Mark** on a product is an assurance of conformity to the specifications. The conformity is ensured by regular surveillance of the licensee's performance by surprise inspections and testing of samples, drawn both from the market and factory.

The Bureau of Indian Standards, empowered through a legislative Act of the Indian Parliament, known as the **Bureau of Indian Standards Act, 1986,** operates a product certification scheme, and has till date granted more than 30 000 licences to manufacturers covering practically every industrial discipline from Agriculture to Textiles to Electronics. The certification allows the licensees to use the popular **ISI Mark**, which has become synonymous with Quality products for the Indian and neighbouring markets over the past 50 years. The Bureau's predecessor, the Indian Standards Institution began operating the product certification Scheme in 1955. Presently more than 19000 licences are in operation covering about 1100 products.

Certification System

The BIS product certification scheme is essentially voluntary in nature, and is largely based on ISO Guide 28, which provides general rules for third party certification system of determining conformity with product standards through initial testing and assessment of a factory quality management system and its acceptance followed by surveillance that takes into account the factory Quality management system and the testing of samples from the factory and the open market. All BIS certifications are carried out in accordance with Indian Standards, which have been found amenable to product certification.

A large number of operational elements of the BIS product certification scheme correspond with the requirements of ISO Guide 65.

Types of Licensing

Although, the scheme itself offers voluntary licensing, the Government of India, on considerations of public health and safety, security, infrastructure requirements and mass consumption has enforced mandatory certification on various products through Orders issued from time to time under various Acts. While BIS continues to grant licences on application, the enforcement of compulsory certification is done by the notified authorities. Given later in this document is a list of items brought under mandatory certification, together with the corresponding Indian Standard Number, and the authorities responsible for enforcing the orders.

Under separate arrangements with Statutory agencies, some products have been placed under special certification schemes of lot or batch inspection carried out by BIS Inspecting officers. A majority of Gas cylinders and valves are certified through such schemes. Under agreement with UNICEF, Deep well hand-pumps, a critical potable water supply source for rural areas is also licensed under a lot inspection scheme.

For all other products, the manufacturer is permitted to self certify the products after ascertaining its conformity to the Standard licensed for. Through its surveillance operations, the Bureau maintains a close vigil on the quality of goods certified.

Operational Areas

The BIS Product Certification Scheme is open to manufacturers in all countries without discrimination. While a licence can be granted for any Indian Standard specifying product characteristics, which is amenable to certification, the broad areas of technologies now under certification are:

- Textiles
- Chemicals and Pesticides
- Rubber and Plastic products
- Cement and concrete products
- Basic metals and fabricated metal products
- Machinery and equipment
- Electrical, electronics and optical equipment
- Automotive components
- Agriculture, food, beverages and tobaccos
- Leather products
- Wood products
- Paper and pulp products
- Testing instruments
- Building materials
- Pumping, irrigation, drainage and sewage equipment
- Packaged drinking water and Natural mineral water
- Pipes and fittings for water supply

British Standards Institution (BSI)

Formed in 1901 by royal charter, BSI is a royal charter organization created to help British industry compete in European and international trade markets. It provides a range of services to its members and to industry in general, from its well known British Standards and excellent standards information facilities to its world renowned mark of product quality, the ‘Kitemark’. BSI also boasts a wealth of technical knowledge gathered over ninety-six years in the business of giving Britain a competitive advantage. BSI was the world's first Standards Making body, and remains to this day as the UK's representative for European and international standardization.

BSI has operated certification schemes to BS EN ISO 9000 since 1979. BSI's registered certification mark, the Kitemark, and its Registered Firm symbol are instantly recognized by customers and suppliers respectively, promoting a company's reliability and commitment to product quality. The Kitemark combines BSI Testing's extensive facilities and ability to certify products against almost any existing British, European or International Standard with the industry sector experience and knowledge gained over many years. The result is a world renowned certificate which carries the authority of BSI.

With the advent of new European legislation in the shape of the New Approach Directives, manufacturers are being forced to look carefully at their products. The directives require manufacturers to ensure that their products are safe and fit for the purpose they were originally intended for before they are put on sale in the community market. Importantly, many of the directives require manufacturers to provide evidence that they have complied with them - in the form of CE Marking. CE Marking can be as simple as devising a technical file, or as complex as regularly submitting your products to third party scrutiny depending on the product. BSI Testing is a Notified Body under many of the directives and can assist manufacturers in complying with this new legislation.

BSI can also offer extensive technical information to customers through its Information service. With access to the largest collection of technical information to customers through its Standards Information service. With access to the largest collection of technical documents in Europe, experts on export regulations and the legal requirements of the New Approach Directives, the Information department can offer excellent consultancy facilities and even offers a technical translation service. BSI's training services offers a wide range of complementary training services including courses on all aspects of ISO 9000 implementation, the new Environmental Management standard ISO 14000, EMAS certification and training courses for assessors and lead assessors to the majority of quality standards.

ISO

ISO is a network of the national standards institutes of 157 countries, on the basis of one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system. ISO is a non-governmental organization: its members are not, as is the case in the United Nations system, delegations of national governments. Nevertheless, ISO occupies a special position between the public and private sectors. This is because, on the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations.

Therefore, ISO is able to act as a bridging organization in which a consensus can be reached on solutions that meet both the requirements of business and the broader needs of society, such as the needs of stakeholder groups like consumers and users.

What ISO's name means: Because "International Organization for Standardization" would have different abbreviations in different languages ("IOS" in English, "OIN" in French for Organisation internationale de normalisation), it was decided at the outset to use a word derived from the Greek isos, meaning "equal". Therefore, whatever the country, whatever the language, the short form of the organization's name is always ISO.

Between 1947 and the present day, ISO published more than 16 000 International Standards. ISO's work programme ranges from standards for traditional activities, such as agriculture and construction, through mechanical engineering, to medical devices, to the newest information technology developments, such as the digital coding of audio-visual signals for multimedia applications.

Standardization of screw threads helps to keep chairs, children's bicycles and aircraft together and solves the repair and maintenance problems caused by a lack of standardization that were once a major headache for manufacturers and product users. Standards establishing an international consensus on terminology make technology transfer easier and can represent an important stage in the advancement of new technologies.

Without the standardized dimensions of freight containers, international trade would be slower and more expensive. Without the standardization of telephone and banking cards, life would be more complicated. A lack of standardization may even affect the quality of life itself: for the disabled, for example, when they are barred access to consumer products, public transport and buildings because the dimensions of wheel-chairs and entrances are not standardized.

Standardized symbols provide danger warnings and information across linguistic frontiers. Consensus on grades of various materials give a common reference for suppliers and clients in business dealings.

Agreement on a sufficient number of variations of a product to meet most current applications allows economies of scale with cost benefits for both producers and consumers. An example is the standardization of paper sizes.

Standardization of performance or safety requirements of diverse equipment makes sure that users' needs are met while allowing individual manufacturers the freedom to design their own solution on how to meet those needs.

Standardized protocols allow computers from different vendors to "talk" to each other. Standardized documents speed up the transit of goods, or identify sensitive or dangerous cargoes that may be handled by people speaking different languages. Standardization of connections and interfaces of all types ensures the compatibility of equipment of diverse origins and the interoperability of different technologies.

Agreement on test methods allows meaningful comparisons of products, or plays an important part in controlling pollution - whether by noise, vibration or emissions. Safety standards for machinery protect people at work, at play, at sea... and at the dentist's.

Without the international agreement contained in ISO standards on quantities and units, shopping and trade would be haphazard, science would be - unscientific - and technological development would be handicapped.

More than half a million organizations in more 149 countries are implementing ISO 9000 which provides a framework for quality management throughout the processes of producing and delivering products and services for the customer.

ISO 14000 environmental management systems are helping organizations of all types to improve their environmental performance at the same time as making a positive impact on business results.

For more examples of the many areas of life and work where ISO standards provide technical, economic and social benefits

Codex

The Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme. The main purposes of this Programme are protecting health of the consumers and ensuring fair trade practices in the food trade, and promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations.

Simply stated, the Codex Alimentarius is a collection of standards, codes of practice, guidelines and other recommendations. Some of these texts are very general, and some are very specific. Some deal with detailed requirements related to a food or group of foods; others deal with the operation and management of production processes or the operation of government regulatory systems for food safety and consumer protection.

The Codex Alimentarius Commission (CAC) was created in 1961/62 by Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme. The main purpose of this Programme is to protect the health of consumers, ensure fair practices in the food trade, and promote coordination of all food standards work undertaken by international governmental and non-governmental organizations.

"Codex India" the National Codex Contact Point (NCCP) for India, is located at the Directorate General Of Health Services, Ministry of Health and Family Welfare (MOH&FW), Government of India. It coordinates and promotes Codex activities in India in association with the National Codex Committee and facilitates India's input to the work of Codex through an established consultation process.

Microbiological Criteria for Safety of Foods

Microorganisms are associated with almost every food item. The microbial types and their quantity in a given food determines its quality and safety. Microbial limits be assigned to at least some foods to designate their safety and overall quality. This concept was suggested way back in 1903 by Marxer who suggested the aerobic plate count (APC) limit of 10^6 for hamburger meat. Subsequently, APC and indicator organisms limits were suggested for many other food products through 1920s and 1930s with pasteurized milk being notable among those for which limits were widely accepted. Microbial limits of various foods is reviewed periodically depending on the products and their quality standards.

The definitions for microbiological criteria of various food items fall into two main categories: mandatory and advisory. A mandatory criterion is a microbiological standard that normally should contain limits only for pathogens of public health significance, but limits for non pathogens may be set. The ICMSF regards a standard as being part of a law or regulation that is enforceable for the regulatory agency having jurisdiction. An advisory criterion is either a microbiological end product specification intended to increase assurance that hygienic significance has been met, (which may include spoilage organisms), or a microbiological guideline that is applied in a food establishment at a point during or after processing to monitor hygiene (it may also include non pathogens). Before recommending a criterion, it is believed that each product must be in international trade, must have associated with it good epidemiological evidence that it has been implicated in food borne disease, and have associated with it good evidence that a criterion will reduce the potential hazard(s) in principle 2 mentioned earlier.

The microbiological criterion consists of five components.

1. A statement of the organisms of concern and/or their toxins
2. The analytical methods for their detection and quantization.
3. A sampling plan, including when and where samples are to be taken.
4. Microbiological limits considered appropriate to the food.
5. The number of sample units that should conform to these limits.

Sampling plans

The above five components are embodied in a sampling plan which is a statement of criteria of acceptance applied to a lot based on appropriate examinations of a required number of sample units by specific methods. It consists of a sampling procedure and decision criteria and may be a two-class or a three-class plan.

A two-class plan consists of the following specifications: n, c, m; and a three-class plan requires n, c, m and M, where

n = the number of sample units (packages, beef patties, and so forth) from a lot that must be examined to satisfy a given sampling plan.

c = the maximum acceptable number, or the maximum allowable number of sample units that may exceed the microbiological criterion m. When this number is exceeded, the lot is rejected.

m = the maximum number or level of relevant bacteria/g; values above this level are either marginally acceptable or unacceptable. It is used to separate acceptable from unacceptable foods in a two-class plan, or, in a three-class plan, to separate good quality from marginally acceptable quality foods. The level of the organisms in question that is acceptable and attainable in the food product is m. In the presence/absence situations for two-class plans, it is common to assign m = 0. For three-class plans, m is usually some non zero value.

M = a quantity that is used to separate marginally acceptable quality from unacceptable quality foods. It is used only in three-class plans. Values at above M in any sample are unacceptable relative to either health hazard, sanity indicators, or spoilage potential.

Products	Tests	Class plan	n	c	m	M	Comments
Precooked breaded fish	APC	3	5	2	$5x10^5$	10^7	
	E.coli	***3***	***5***	***2***	***11***	***500***	
	S.aureus	3	5	1	10^3	10^4	Products likely to be mishandled
Raw chicken(fresh or frozen) during processing	APC	3	5	3	$5x10^5$	10^7	In-plant processing
Frozen vegetables and fruits	*E.coli*	3	5	2	10^2	10^3	m value is estimate
Comminuted raw meat (frozen) and chilled carcass meat	APC	3	5	3	10^6	10^7	In-plant control
Cereals	Molds	3	5	2	10^2-10^4	10^5	m values are estimates
Frozen centres containing Rice or corn flour	*S. aureus*	3	5	1	10^3	10^4	m value is estimate
Noncarbonated natural mineral and bottled noncorbonated waters	Coliforms	2	5	0	0	-	Not for use in infant formula or use by highly susceptibles
Roast beef	*Salmonella*	2	20	0	0	-	
Frozen raw crustaceans	*S. aureus*	3	5	2	10^3	10^4	
	V. parahaemolyticus	3	5	1	10^2	10^3	
	Salmonella[a]	2	5	0	0	-	
	APC[b]	3	5	2	$5x10^5$	10^7	
	E.coli[b]	3	5	2	11	500	
	S.aureus[b]	2	5	0	10^3	-	

[a] Normal plans and limits, [b] Additional tests where appropriate.

Table 3: International Commission on Microbiological Specifications for Foods (ICMSF) sampling plans and recommended microbiological limits

Note: Except where noted for in-plant use, they are intended primarily for foods in international trade and are cited here primarily to illustrate the assignment of products to case and limits on a variety of organisms. The ICMSF should be consulted for methods of analysis and more details in general

Source: Modern food microbiology by James M. Jay. Pub: CBS Publishers & Distributors, New Delhi.

Microbiological criteria and food safety

Application of criteria to products in the absence of a HACCP program is much less likely to be successful than when the two are combined. Thus, microbiological criteria are best applied as part of a comprehensive program. When criteria are not applied as components of systematic approach to food safety or quality, the results are known to be less than satisfactory. The microbiological guidelines employed for raw and ready to eat foods are given in Table below. Prior to the development of the HACCP and sampling plan concepts, microbiological (generally referred to as standards at the time) were applied to a variety of products by various organizations along with federal, state and city standards in effect.

Suggested Readings

1. Microbiology. Pelczar, M.J., Chan, E.C.S. and Krieg, N.R. Publ: McGraw-Hill Book Company, New Delhi
2. Food Microbiology. Frazier, W.C. and Westhoff, D.C. Publ: Tata McGrah-Hill Publishing Company, New Delhi
3. Modern Food Microbiology. James M. Jay. Publ: CBS Publishers & Distributors. New Delhi
4. American Public Health Association. Standard Methods for the Examination of water and Wastewater. Washington, D.C. APHA
5. ICMSF 1986. Microorganisms in Foods. Vol. 2. . Sampling for Microbiological Analysis: Principles and Specific Applications. University of Toronto Press, Toronto
6. ICMSF 1988. Microorganisms in Foods. Vol. 4. Application of the Hazard Analysis Critical Control Point (HACCP). Systems to ensure Microbiological Safety and Quality. Publ: Blackwell, London