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HANDBOOK ON BASIC Food Safety for health professionals
Dr. Dwi Nastiti Iswarawanti M.Sc
Evi Ermayani M.Nutr
Arienta R.P. Sudibya M.Sc

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II. Hygiene
III. Health Professionals
IV. Sanitation

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FOREWORD

Food-borne disease is known not only to impact our health status but also contributes to affect the overall economic and social welfare. Food safety education is one of the elements for the prevention of food-borne diseases. This book provides principles in food safety and is developed for health professionals for further use in food safety education for the public.

As part of SEAMEO RECFON's commitment in education and capacity building for professionals in the fields of food, nutrition, and health, the development of teaching modules is recognized as one component to achieving program excellence in our teaching program.

It is our pleasure to present the book that may serve as an essential reference for understanding the potential hazards exposing foods in our surrounding. We hope that through the book and the training, we can cultivate some prevention measures for the development of food-borne diseases through the application of food safety and hygiene in our daily life.

We wish you to find the book as a happy reading.

Jakarta, November 2018

Muchtaruddin Mansyur, MD, PhD
Director SEAMEO RECFON

PREFACE

Foodborne diseases, particularly those caused by pathogenic microorganisms, remain a serious problem worldwide. Health professionals, including nutritionists, have a significant role to prevent and reduce the incidents in the community. Knowledge on food safety is necessary in order to advise and educate the population on safe preparation. Health professionals should understand the epidemiology of the principles of foodborne diseases caused by biological, chemical as well as physical hazards and use a preventive approach to ensure the food safety system, namely Hazard Analysis Critical Control Points.

To facilitate the mentioned issues, SEAMEO RECFON developed a post graduate training package including this book. The training package is intended for health professionals in the area of health, food and nutrition who needs a basic understanding of food safety.

The book aims to provide information on:

1. The nature and magnitude of foodborne diseases and their health and socioeconomic impacts
2. The biological, chemical and physical hazards on food
3. The factors influencing the growth and survival of pathogen micro-organisms and food technology to control them.
4. Good Hygienic Practices
5. Hazard Analysis Critical Control Points (HACCP) approach

This book also provides the glossary terms and foodborne disease profiles which the majority were developed by WHO. For those who never received any food safety training, it is suggested to read the glossary of terms to get a clear understanding. Information on foodborne diseases profiles is necessary for those who need to use HACCP approach or develop the document.

Jakarta, December 2018

D. N. Iswarawanti
Evi Ermayani
Arienta R.P. Sudibya

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IMPACT OF FOODBORNE DISEASES

Foodborne diseases can be defined as: "any disease of an infection or toxic nature caused by the consumption of food (or water)". Foodborne diseases or foodborne illness are now the preferred term used. The term of "food poisoning" has often been used but sometimes it may be misleading since it only refers to toxin-caused illnesses.

Food safety assures that food will not give adverse effect or harm to consumers when it is prepared and/or eaten according to its intended use (codex, 1997). This "adverse effect" or "harm" in food safety refers to foodborne diseases or illnesses caused by microorganisms such as bacteria, virus, mold, or parasites; chemical such as pesticide residue, or chemical additional materials in food, or harm from physical hazard such as stone, nails, steel etc. Worldwide, foodborne diseases caused by microorganisms have caused morbidity and mortality, and also significantly impact the socioeconomic status of consumers as well as the country. Nevertheless, the burden of food borne diseases caused by chemical and parasites are still unknown.

1.1. Impact to health and nutritional status

WHO estimated in 2015, there were 31 foodborne hazard affecting 32 diseases. The most frequent causes of the illness were diarrheal agents, which caused 230,000 deaths (95% UI 160,000-320,000), especially norovirus and *Campylobacter* spp., and *Salmonella enterica* which causes diarrheal and invasive diseases. No one has immunity to foodborne diseases, thus foodborne diseases are more prone to vulnerable groups, such as children. In 2010, there were 40% children under five years of age affected by food borne diseases (WHO, 2015).

Foodborne diseases usually occur when associated with personal hygiene and food hygiene practices during food preparation. Cholera, which was largely found in poor communities with poor public health facilities, spread faster when there are inadequate toilet facilities, including clean water availability, poor personal hygiene, contaminated food and lack of personal and food hygiene knowledge. Related with microbiological hazard, factors contributing to the food illnesses are contamination of food through unclean equipment and cross contamination, survival of microorganism from insufficient food handling such as inadequate cooking or reheating, and growth of microorganisms from insufficient freezing.

Table 1. Health Outcomes of Selected Foodborne/Waterborne Pathogens[1]

Type	Name	Health Outcome	Note
Bacteria	*Brucella*	Epididymo-orchitis – inflammation of one or both of the testicles. Meningitis – inflammation/infection of the membranes covering the brain and spinal cord. Pericarditis – inflammation of the sac-like covering around the heart (pericardium). Spondylitis – inflammation of the joints between the spinal bones and the joints between the spine and thepelvis.	
	Campylobacter	Carditis – inflammation of the muscle tissue of the heart. Cholecystitis – inflammation of the gallbladder that can cause severe abdominal pain. Endocarditis – infection of the inside lining of the heart chambers and heart valves. Guillain-Barré syndrome – body's immune system attacks part of the peripheral nervous	Permanently disabled and paralyzed. Campylobacter can trigger arthritis, heart infections, and blood infections
	Escherichia coli O157:H7	Hemolytic uremic syndrome (HUS)* – a disorder that usually occurs when infection in the digestive system produces toxic substances that destroy red blood cells. HUS can affect all body organs, resulting in: kidney failure; hypertension; neurological problems; diabetes; digestive problems; gallstones; irritable bowel syndrome; intestinal strictures, and pneumonitis (infection of the lung from food or vomit).	Kidney failure in children. In long term: including end-stage kidney disease, neurological complications, and insulin-dependent diabetes
	Listeria monoytogenes	Infections of brain and spinal cord	Serious neurological dysfunctions Death, most cases occurs in children Miscarriage, premature deaths, still birth – pregnant women Listeriosis survivors: serious neurological dysfunction, including seizures, paralysis, and impaired ability to see, hear, swallow or speak. Severe cases: partial to total impairment, require life-long residential care with no possibility of work
	Salmonella	Aortitis – inflammation of the aorta. Cholecystitis – ***see Campylobacter Colitis*** – inflammation of the large intestine. Endocarditis – ***see Campylobacter Epididymo-orchitis – see Brucella Meningitis – see Brucella*** Myocarditis – inflammation of the heart muscle. Ostemyelitis – infection of bone or bone marrow. Pancreatitis – inflammation/infection of the pancreas. Reactive arthritis – ***see Campylobacter*** Septicemia – ***see Campylobacter*** Splenic abscesses – a high level of pus in the spleen caused by a bacterial infection.Septic arthritis (sickle-cell anemic persons) – inflammation of a joint caused by a bacterial infection; also known as infectious arthritis.	Painful and swollen joint
	Shigella	Hemolytic-uremic syndrome – ***see Escherichia coli O157:H7*** Reactive arthritis – ***see Campylobacter*** Splenic abscesses – ***see Salmonella*** Synovitis – inflammation of the synovial (joint)	Painful and swollen joint
	Toxoplasma gondii	Impairment fetus from acute fetal or newborn infection	Mild to severe mental retardation, moderate visual impairment, crossed-eyes, some cases blindness in one or both eyes
	Vibrio para-haemolyticus	Septicemia – ***see Campylobacter***	
	Yersinia	Cholangitis – infection/inflammation of common bile duct. Liver and splenic abscesses – high level of pus in the spleen and/ or liver. Lymphadenitis – infection/inflammation of the lymph nodes. Pneumonia – infection of the lungs. Pyomyositis – bacterial infection of skeletal muscle which results in abscesses. Reactive arthritis – ***see Campylobacter Septicemia – see Campylobacter*** Spondylitis – ***see Brucella***	
Paracites	*Taenia*	Cysticercosis – illness caused by a parasite called *Taenia solium* (T. solium), a pork tapeworm that creates cysts and can affect the brain; spinal cord; muscles; eyes.	Mild to severe mental retardation, moderate visual impairment, crossed-eyes, some cases blindness in one or both eyes
	Toxoplasma gondii	Central nervous system diseases – any one of the diseases that involve the brain or spinal cord. Encephalitis – inflammation of the brain. Mental retardation. Pancarditis – inflammation of the entire heart. Polymyositis – type of inflammatory myopathy, which is characterized by muscle inflammation and weakness. Retinochoroiditis — inflammation of the retina and choroid.	
	Trichinella	Myocarditis – ***see Salmonella*** Myositis – inflammation of skeletal muscles that can cause pain (myalgia) and weakness.	
Virus	*Hepatitis A*	Liver disease	

[1]adapted from Roberts T, Barbara K, Patricia B.
The Long-Term Health Outcomes of Selected Foodborne Pathogens.
The Center for Foodborne Illness Research and Prevention. 2009

1.2. Impact to socio economic status

Food safety is essential for the health and the livelihood of the community as well as for the macro system, such as economic and social welfare at the country level. Food safety issues in one country should be considered important by other countries since food supply chain in the global trade market nowadays are very complex. For example, a microbiological outbreak in one country which was found in raw vegetables, should be taken seriously by other countries which import vegetables from the country where the outbreak happen. The impact of food safety outbreaks could be overwhelming. When it is economically counted, one single incident of a foodborne disease outbreak can bring incredible economic losses. Nevertheless, social impact could be arising that is priceless.

There are three areas or level of impact of foodborne diseases: impact on individuals, food company or industry, and impact on a country or state. Economic impact on individuals are generally counted based on health condition and other cost related factors. Economic losses from the food safety aspect are quantified from financial lost due to the sickness, which includes medical treatment such as doctor's payment, drug or medicine, and hospitalization, salary lost due to work absence and other disadvantages that could arise.

The losses for food companies or food industries go beyond. Food borne diseases (outbreak) for internal company means absenteeism and loss of productivity, and externally it goes to product recall, loss of market or consumer demand, loss of image and the worst could be termination of company. When the root cause of a food borne disease outbreak comes from an industrial food product which affects the public, it may cause the termination of the company and long-term impairment to a specific sector of food industry.

Impact of food borne diseases at country level could reach multi sector. Using an example above, an incidence of a microbiological outbreak, for the country could have an impact on the reduction of exports, unemployment, surveillance cost, outbreak investigation etc. Social security systems due to food borne disease in every country is treated differently. It depends on the economic condition (low, middle or high income country) and the social system developed by the country.

Table 2. Economic Impact of Food Borne Disease

Individual	Food Companies/ Food Industries	Country/ State
- Medical cost - Income loss - Child care cost - Rehabilitation cost - Pain and suffering	- Absenteeism - Productivity loss - Product recall - Loss of market/ consumer demands - Loss of image - Legal cost - Insurance administration - Termination of manufacture/ company	- Unemployment - Outbreak investigation - Surveillance cost - Reduced exports - National - productivity loss - Tourism loss - Human resource loss - Social security loss - Medical care cost

The socio economic impacts of food borne diseases are very serious and have significant cost. It is knowledgeable that investing prevention programs is cheaper than the cost of an actual outbreak. Thus, it is important to have preventive program and actions, not limited to increasing food safety awareness, monitoring the food chain supply, and maintaining qualified food production.

2

2 FOOD BORNE PATHOGENS

Microorganisms are extremely small. One cup of yoghurt may contain 120.000.000.000 separate living organisms. Bacteria divide asexually by binary fission. Bacteria can exchange genetic material in a process called conjugation, where simple circular strands of DNA called plasmids are passed from one to the other. Under optimum conditions, bacteria can duplicate every twenty minutes.

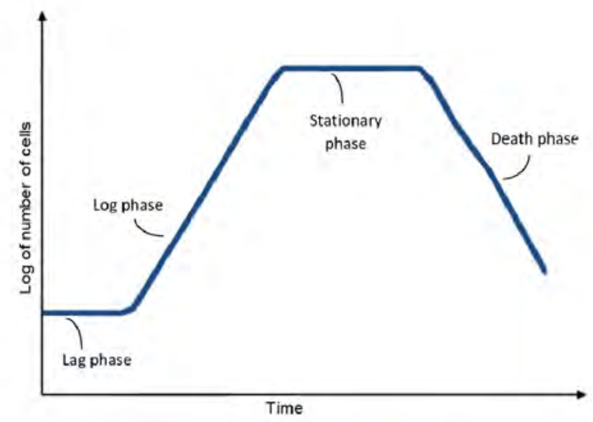


Figure 1. Graph of Bacteria Growth

This graph shows the increase of bacteria with time, and its relation to spoilage and toxin production.

At first, bacteria adapt to their surroundings and do not divide; this is the *lag phase of growth*. The next period is called the *logarithmic growth phase*, because the numbers increase exponentially (we have used a logarithmic scale on the Y axis, so this phase appears as a straight line). The time needed for the number of organisms to double is the *generation time*. After a while, the production of toxic by-products such as acids, and the depletion of growth substrates such as carbohydrate, essential amino acids, or oxygen, limit further growth. The curve flattens; this is the stationary phase.

Toxins are produced towards the end of the logarithmic phase and during the stationary phase of the growth curve. Since toxin formation may occur before microbial growth produces visible changes, a seemingly acceptable food can cause an intoxication.

2.1. Infectious foodborne pathogens

Several pathogens are able to invade the body and multiply in the tissues of the gut and other organs. The infectious dose is determined by several factors, namely host, organism and food.

Host. The state of the host is important; age and immune status are critical, and perhaps related. The seriousness of the infection also depends on the state of the patient. Young children, pregnant women, old people and people who are ill tend to be more severely affected than healthy adults. Young children are particularly likely to become sick, and the elderly have a high fatality rate. We know very little about the factors affecting immune status but certainly, malnutrition is one of them. Gastric acid is one of the first barriers to infection; its pH may change according to the food. The gut flora may also be important since they can help prevent the establishment of pathogens. Certain infections, such as listeriosis and toxoplasmosis, may be of concern to pregnant women, because of the high susceptibility of the unborn child.

Organism. The organism is also important, whether it is sporulated or in the vegetative state. Some strains have special characters such as fimbriae which help them to attach to the gut. These contribute to the virulence of the strain. However, the outcome of infection is related to the interaction of the state of the host and the organism.

Food. The type of food can play a role. Fatty foods may form an insoluble layer of fat around the micro-organism, thus protecting it from the bactericidal effects of gastric acid. In outbreaks of salmonellosis linked to chocolate and cheese, the number of organismes present was very low. The acidity of the stomach is a major barrier to infection. This may vary with the type of food. Milk products can reduce acidity due to the buffering power of casein. The use of anti-acid medicines can also increase susceptibility to foodborne disease.

Some pathogens that frequently reported infected human body and cause illness are:

- *Salmonella* spp
- *Campylobacter* spp
- *Escherichia coli* (certain strains)
- *Vibrio parahaemolyticus*
- *Vibrio cholerae*
- *Yersinia enterocolitica*
- *Aeromonas hydrophila*
- *Listeria monocytogenes*

There are many infectious pathogens, however this book will elaborate only some major pathogens such as salmonella, campylobacter and *E. coli*.

Salmonella

Salmonella spp. are a group of bacteria which reside in the intestinal tract of human beings and warm blooded animals and are capable of causing disease. They are facultative anaerobic Gramnegative rods.

Characteristics of Salmonellosis

- *Main symptoms*
  - diarrhoea
  - fever
  - abdominal cramps
  - vomiting
- *Persons at high risk*
  - young
  - old
  - pregnant women
  - immunocompromised
  - underlying disease states
- *Fatality rate*
  - < 1%
- *incubation period*
  - usually 12-36 hours

As we shall see later, salmonellosis is one of the most common FBDs, particularly in industrialised countries. We can see that the categories of people most at risk are the ones we just mentioned. The mortality is low in the general population, although it can be higher if an outbreak occurs in a hospital or nursing home, or if proper rehydration is not available. The disease called "typhoid" is also caused by *Salmonella*. However, typhoid is a generalized disease while the salmonellae discussed here usually cause gastro-enteritis.

There are more than 2000 serotypes of *Salmonella* that can be identified in the laboratory. 200 of these have been associated with FBD in Europe. 70% of the cases are caused by two types: S. enteritidis and S. typhimurium.

We can further distinguish between the serotypes by phage typing. This technique looks at the sensitivity to bacteriophage viruses that specifically attack the genus.

Raw food materials likely to be contaminated by Salmonella namely:

- Poultry
- Meat
- Milk
- Eggs
- Vegetables
- Shellfish
- Spices and herbs
- Untreated water

These organisms live in the gut of warm-blooded animals and birds. They can be isolated from the environment, where they are transmitted from faeces and where they can survive. Poultry and eggs are a major source of Salmonella, particularly *S.* enteritidis which infects chickens. Other meat is less likely to be associated with it. In Europe, milk tends to be associated with S. typhimurium. Contaminated irrigation water can transmit a variety of serotypes to vegetables. Shellfish can be contaminated by sewage discharged into the sea and rivers. Spices which are dried in the open air can be exposed to animals and birds.

Even though the organisms may be found in raw materials, standard heat treatments, applied in the presence of sufficient moisture, usually will kill them. Some strains are particularly heat resistant. However, 70°C for 2 minutes is usually sufficient to kill 106 Salmonella (vegetative stage).

Figure 2. A Scanning Electron Micrograph of *Salmonella spp.*
Source: NIH, 2005

Campylobacter

Campylobacter spp are fragile. They survive only for seconds at 60°C and sensitive to drying although they may survive in frozen meat and poultry. They require special low oxygen conditions to grow and thus, do not normally grow in foods.

Characteristics of campylobateriosis

- Main symptoms
  - mild to severe diarrhoea
  - fever

  - nausea
  - abdominal cramps
- persons at risk
  - babies and young people
  - debilitated people
- incubation usually 2-5 days

In many countries, campylobacteriosis is rapidly overtaking salmonellosis as the most frequently reported cause of enteric disease. It is caused by a spiral organism commonly found in poultry and in other birds, which may well be a normal gut inhabitant, since it is found in free range poultry. *Campylobacter coli*, which infect pigs in some countries and poultry in others, can cause human illness.

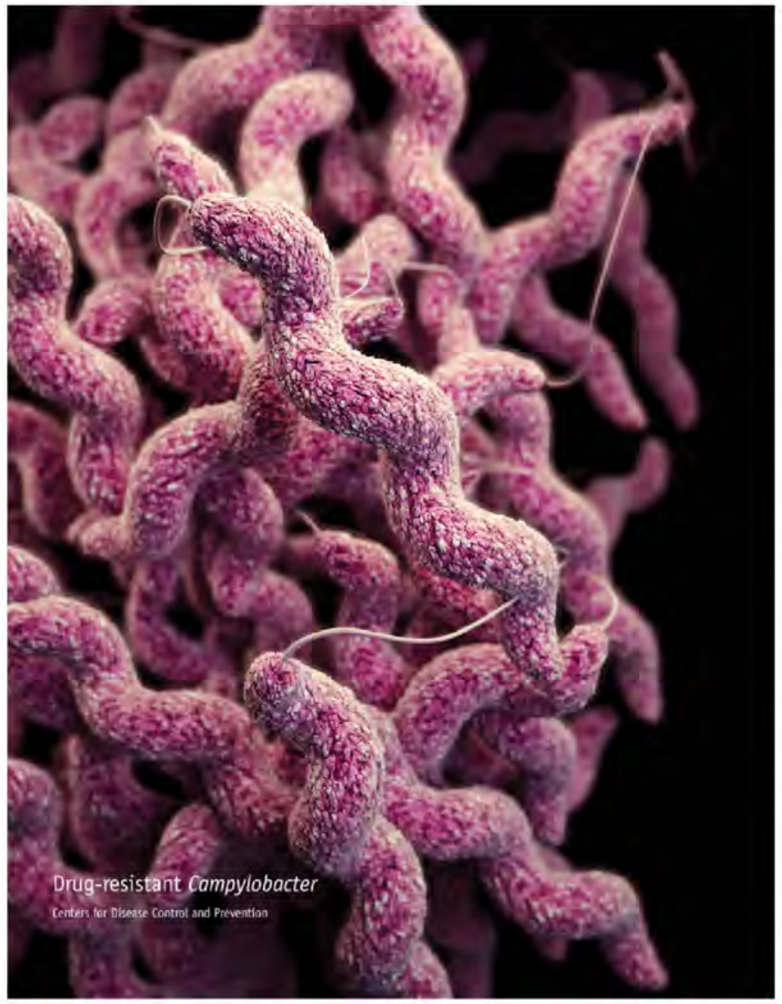


Figure 3. A Scanning Electron Micrograph of *Campylobacter spp.*
Source: CDC, 2013

Escherichia coli

Escherichia coli is one of the organisms most familiar to bacteriologists. It is a normal inhabitant of the gut of warm-blooded animals, including man, and birds. Although we all have it in our gut, we may not readily accept *E. coli* from outside sources. The organism is obviously adapted to this niche, which also means that some strains may have characteristics that favour their colonisation over other strains. This may be the reason that the organism can cause disease.

Four types of disease have been recognised, each with different symptoms.

- *Enteropathogenic E. coli* (*EPEC*) - Acute watery diarrhoea - young children particularly susceptible
- *Enteroinvasive E. coli* (*EIEC*) - Dysentery-like syndrome
- *Enterotoxigenic E. coli* (*ETEC*) - Acute watery diarrhoea - often in travellers
- *Enterohaemorrhagic E. coli* (*EHEC*) - Bloody diarrhoea syndrome

Incubation of pathogen is 8-44 hours depending on type. Diarrhoea due to this organism is probably one of the most common causes of morbidity in young children. The symptoms of the different types of disease vary in severity. When travelers adjust to the microflora of different countries, they often experience a mild form of diarrhoea. Lately, *Enterohaemorrhagic* E. coli O157:H7 has emerged in the USA, Europe, Japan and Africa as the cause of not only severe enteritis, but of subsequent kidney disease, which can be fatal, and is particularly likely to affect children.

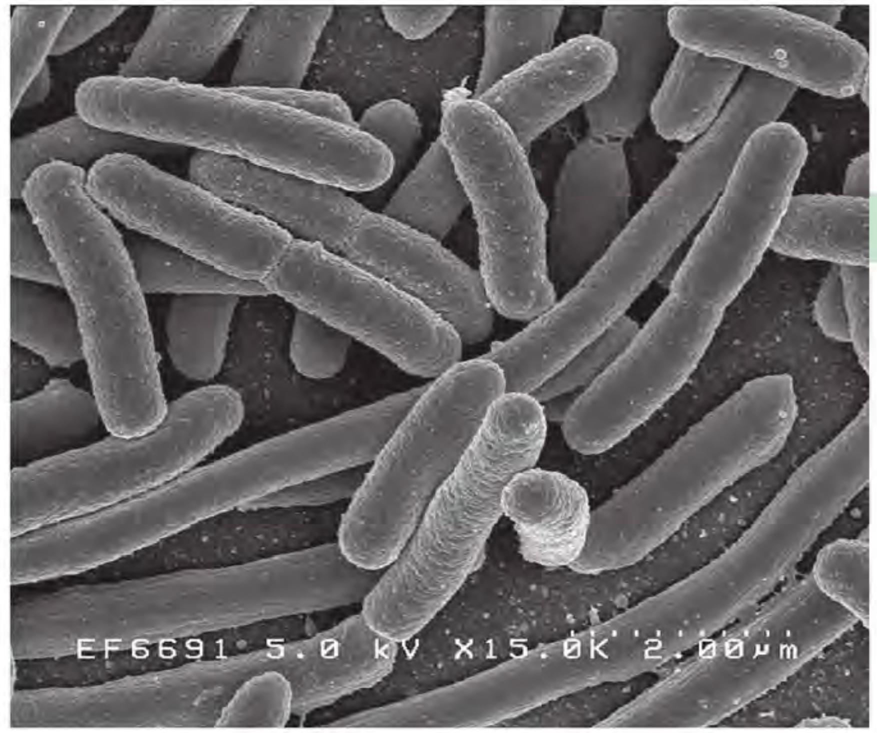


Figure 4. A Scanning Electron Micrograph of Escherichia coli.
Source: Rocky Mountain Laboratories, NIAID, NIH, 2005.

Below are some raw food materials that likely to be contaminated by *E.coli*:

- Meat and its products
- Fish and its products
- Vegetables
- Milk and its products
- Polluted water

2.2. Toxigenic foodborne pathogens

Some microorganisms produce toxins rather than invading the host tissue. It is not fully understood the purpose of toxins in the physiology of the many organisms. However, they often have devastating effects on the host. There are only a few of the bacteria that produce toxins. Foods which contain this toxin may cause intoxication. Bacteria that produce toxin in the exponential phase of growth generally require the presence of fewer cells before a food becomes toxic. There are some microorganisms which frequently occurs producing toxin, namely *Bacillus cereus*, *Clostridium botulinum*, and *Staphylococcus aureus*. The minimum toxic doses of these bacteria are as follow:

- *Bacillus cereus*: 10^7 - 10^8 (cells /g)
- *Clostridium botulinum*: 10^4 - 10^5 (cells /g)
- *Staphylococcus aureus*: 10^6 (cells /g)

The toxic dose for *B. cereus* is comparatively high, indicating either that toxin is produced in the stationary phase, or that it is necessary to ingest high numbers of spores that go on to germinate in the gut.

Bacillus cereus

Intoxication by this organism is much more common than that with botulinum toxin. The onset is rapid and two syndromes are seen, the diarrhoeal syndrome being more common than the emetic syndrome. In foods associated with outbreaks, large numbers of bacteria have been detected. This intoxication is unpleasant but rarely fatal.

Table 3. Characteristics and Syndromes of *Bacillus cereus*

Characteristic	Diarrhoeal Syndrome	Emetic Syndrome
onset of symptoms	4 - 16 hours	1 - 14 hours
duration of symptoms	12 - 24 hours	6 - 36 hours
symptoms	abdominal pain, watery diarrhoea	nausea and vomiting
number of bacteria in incriminated food	10^8 / g	10^8 / g

At sterilisation temperatures, the spores are killed rapidly. Thermal resistance of *Bacillus cereus* is D-value of 0.02 - 0.06 minutes at 121°C = 0.3 - 27 minutes at 100°C. At lower temperatures, a prolonged exposure is required to kill the organism and its spores.

Food materials that is likely to be contaminated by *B. cereus*:

- Raw foods
  - o Cereals
  - o Dried vegetables
  - o Potatoes
  - o Milk
  - o Cream
  - o Rice
  - o Spices
- Cooked / processed foods
  - o Roast / fried meat products
  - o Soups
  - o Cooked / fried rice meals

Since it is a common terrestrial organism, many foods can be contaminated by *B. cereus*. However, it is most frequently associated with cooked rice products kept at room temperature. Although it is found in milk, no milk-related outbreaks have been reported.

Clostridium botulinum

There are 2 types of *Clostridium botulinum* proteolytic and non- proteolytic. The proteolytic and non-proteolytic strains have different properties. It is important to take this into account when developing safe foods.

Table 4. Characteristics of *Clostridium botulinum*

Characteristics	Proteolytic	Non- proteolytic
Onset	12-36 hours	SAME
Duration	days to several months	SAME
Symptoms	nausea, vomiting, visual disturbances, vertigo	SAME
Toxic dose	0.005-0.1 µg	0.1-0.5 µg
Toxin types	A, B, F	B, E, F
Minimum pH	4.6	5
Maximum NaCl	10 %	3 %
Minimum aw	0.93	0.97
Temp. range for growth	12.5 - 48°C	3.5 - 48°C
Decimal reduction time of spores at 100°C	25 min.	<0.1 min.

The onset of intoxication with botulinum toxin is variable. In severe cases, the symptoms may persist for several months. Nausea and vomiting occur, due to an action not at the enteric level but at the level of the central nervous system. Visual disturbance, due to decreased co-ordination of the eye muscles, is often seen quite early. In severe cases, the respiratory muscles are paralysed and artificial life support is necessary. The different types of the organism produce toxins of different toxic doses.

Staphylococcus aureus

Intoxication by *S. aureus* can be serious; the onset of symptoms is rapid 6 – 24 hours. It can cause dehydration and shock followed by prostration. It causes violent diarrhoea and vomiting but no fever. Absence of fever is quite common in cases of intoxication. Incubation period is 1 – 6 hour.

Main symptoms :

- o Nausea
- o Vomiting
- o Diarrhoea
- o Abdominal pain
- o NO fever
- o Collapse and dehydration in severe cases

The toxin is formed when the organism grows in food and the symptoms occur after ingesting the preformed toxin. Enterotoxin highly heat - resistant (not inactivated by boiling at 100°C) which means that although there may be no organisms detectable in the food, the toxin remains. It has D - value at 77°C ~ 0.001 - 0.0105 minutes and z = 8 -- 12°C.

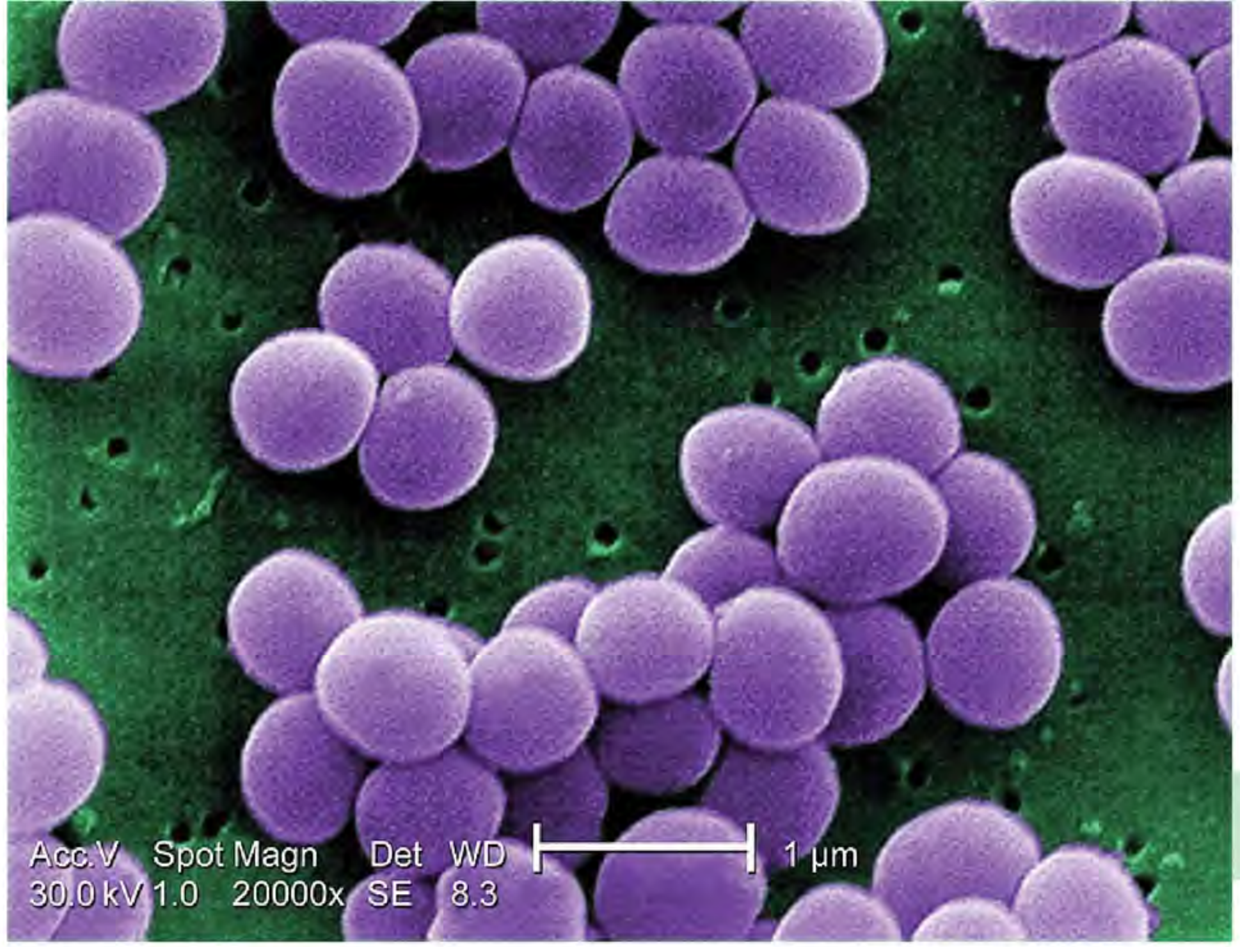


Figure 5. A Scanning Electron Micrograph of *Staphylococcus aureus*

Source: Arduino and Carr, 2001.

2.3. Other microbial hazards: virus, fungi and parasites

Other microbial hazards than often to be occurred are virus, fungi and parasites. Major viruses causing foodborne disease are:

- Hepatitis A and E viruses
- Small Round Structured Viruses (e.g. Norwalk agent)
- Rotavirus
- Polio virus

Whereas major mould/fungi causing foodborne disease are:

- *Aspergillus* spp.
- *Fusarium* spp.
- *Penicillium* spp.

Main associated foods with the hazards are fruits, nuts and grains. Very few virus particles are required to infect a host. Sometimes as few as 10 - 100 particles per ml are sufficient. Techniques such as electron microscopy or immunoassays can detect as few as ten thousand particles per gram of sample. Genetic techniques can detect even smaller numbers of virus particles.

Major parasites (protozoa and helminths) causing foodborne diseases are:

Protozoa : *Cryptosporidium sp; Entamoeba histolytica; Giardia; Toxoplasma; Helminth : Angiostrongylus; Anisakis; Ascaris; Capillaria; Gnathostoma; Trichinella; Fasciola; Fasciolopsis; Haplorchis; Opisthorchis; Paragonimus;Cysticercus cellulosae.*

3

3 FOOD CHEMICAL HAZARDS

Chemical agents are used along the food chain with purpose to improve and ensure the quality and quantity of products. Any chemical that can cause harm is a hazard. Therefore, the risk to the safety of consumer needs to be considered. The presence of chemical hazards may occur as biological sources, industrial pollution, agricultural practices and others. The main biologically-derived hazards are inherent food plant toxicants, mycotoxins, and other toxicants of biological origin. Industrial and environmental contaminants, such as dioxins, polychlorinated biphenyls and the heavy metals, are widely known as posing a serious threat to human health. A small but important group of contaminants can be produced during processing. Substances such as additives, pesticides and animal drugs have also caused intoxications, but are safe if used properly. Some chemicals can provoke allergic reactions, even at low levels, posing a life-threatening hazard for sensitive individuals.

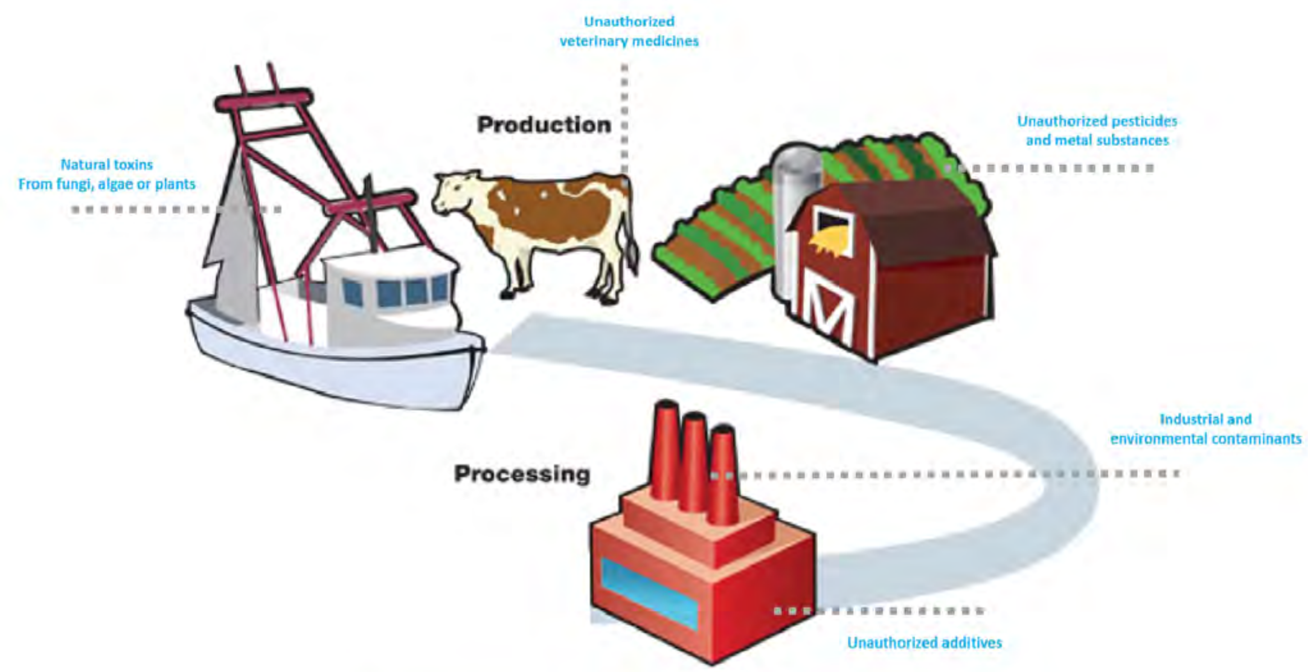


Figure 6. Food Chain Where Chemical Agents are Used

3.1. Biological sources

Many plants contain components that may be toxic to humans and animals. Some, such as cassava and red kidney beans, are safe for consumption if processed properly. Others, including many spices, contain naturally occurring known or suspected carcinogens, such as alkyl isothiocyanate (garlic), capsaicin (hot chilli peppers) and apiol (parsley, celery, parsnips). Consumption of insufficiently processed cycad flour has been associated with a delayed neurotoxic syndrome in Guam, Japan and Papua New Guinea.

Table 5. Associated Foods with Inherence Toxicants

Chemical	Associated food
Oxalates	rhubarb, tea, cocoa, spinach, beet
Glycoalkaloids	green potato
Cyanoglycosides	lima bean, cassava
Phytohaemagglutinin	red kidney beans and other beans
various carcinogens	spices and herbs

Mycotoxins are poisonous substances produced by fungi, and have caused outbreaks of mycotoxicosis in humans and in livestock. Many outbreaks have been linked to eating mouldy food and feed because of food shortages or because of ignorance of the risks. Such practices continue in many parts of the world.

Mycotoxins have also been linked to many chronic diseases, including cancer. Public health officials are beginning to recognise the importance of the problem. The Food and Agricultural Organization (FAO) of the United Nations has estimated that 25% of the world's food crops are contaminated by mycotoxins. A study in Asia and Africa estimated that 10 to 50% of crops are contaminated. In a Japanese study of *Fusarium* toxins in widely separated countries, only a few samples were not contaminated.

Table 6. Associated Food Reported Contaminated by Mycotoxins

Mycotoxin	Source	Associated food
Aflatoxin	*Aspergillus flavus* and *A. parasiticus*	corn, peanuts, tree nuts, milk
Trichothecenes	Mainly *Fusarium*	cereals and other foods
Ochratoxin A	*Penicillium verrucosum A. ochraceus*	wheat, barley, corn
Ergot alkaloids	*Claviceps purpurea*	rye, barley, wheat
Fumonisins	*Fusarium moniliforme*	corn
Patulin	*P. expansum*	apples, pears
Zearalenone	*Fusarium spp*	cereals, oil, starch

Aflatoxins are carcinogenic for all animal species studied, including man. Aflatoxins and hepatitis B virus are cocarcinogens, with increased risk of liver cancer if both factors are present. Ochratoxin A causes kidney damage in humans. Trichothecene produces a variety of symptoms in humans, including dermatitis, cough, rhinitis and haemorrhage in the nose, but immunosuppression is the underlying cause. The trichothecene T-2 was responsible for the deaths of tens of thousands of people in Russia from 1942-1947, due to its build up in grain left in the field over winter. Throat cancer in parts of China and Africa is probably linked to fumonisins in corn. Ergot alkaloids, besides their historical notoriety for their acute effects, continue to be a concern because of other possible vascular effects. Zearalenone is structurally similar to diethylstilbestrol (DES); there are a number of unanswered questions about the effects of estrogenic substances in food.

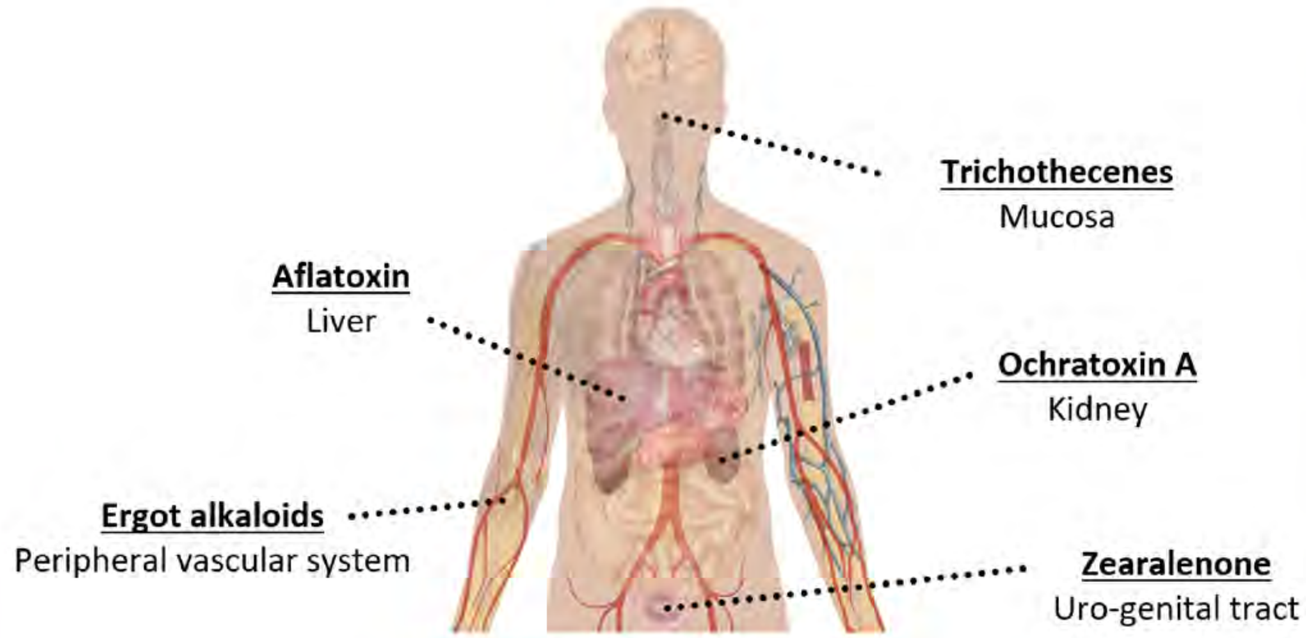


Figure 7. Target Organs of Mycotoxins

Many governments have established limits for mycotoxins, particularly aflatoxins. Ideally, such limits should be based on scientific risk assessment of the toxicity of the mycotoxin and estimated likelihood of exposure. However, risk assessment data are incomplete for many mycotoxins, so most established limits are based on Good Agricultural and/or Good Manufacturing Practices. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) is using human epidemiology studies to develop a quantitative risk assessment of aflatoxin.

Table 7. Regulatory Limits of Mycotoxins in Foods

Mycotoxin	Limit (µg/kg)	Comodities	No of Countries
Aflatoxins	0 - 50	corn, peanuts, other foods	48
Aflatoxin M_1	0.05 - 1.0	milk, dairy	17
Ochratoxin A	1 - 300	rice, corn, barley, beans, pork kidney	6
Deoxynivalenol	1000 - 4000	wheat	5
Patulin	20 - 50	apple juice	10
Zearalenone	30 - 1000	all foods	4

Table 8. Other Toxicants with Biological Origin

Toxicant	Source	Associated food
Ciguatera	dinoflagellates	tropical Fish
Shellfish toxins	dinoflagellates	shellfish
Pyrrolizidine alkaloids	*various toxic plants*	cereals, honey
Histamine	*spoilage bacteria*	fish, cheese

This list does not include all poisonous plants and animals; only the most widespread. Ciguatera is found mainly in tropical reef fish. Since it accumulates in the food chain, large predatory fish are the most toxic. Poisoning causes gastrointestinal, cardiovascular and neurological symptoms, such as a reversal of hot/cold sensations. Other dinoflagellates produce shellfish poisonings. While dinoflagellates have specific geographical ranges, "blooms" have occurred outside traditional areas because of climate changes. Pyrrolizidine alkaloids, which can cause liver damage, are found in plants that may be consumed unintentionally with edible plants. Histamine is usually associated with decomposing scombroid fish, produced by the decarboxylation of histidine by bacteria. Usually, tingling, rash or drop in blood pressure occurs within 30 minutes of ingestion, and symptoms disappear after 3 hours.

3.2. Industrial pollution from environmental and process

There are contaminants produced during processing such as:

- Polynuclear aromatic hydrocarbons
- Heterocyclic amines, nitropyrenes
- Nitrosamines
- Ethyl carbamate (urethane)
- Chloropropanols

Toxic contaminants, including potential carcinogens, can be produced during food processing. High levels of benzo[a]pyrene can be produced in food during charcoal grilling; heterocyclic amines and nitropyrenes are produced when meat and fish are exposed to high temperatures. Nitrosamines, which are known carcinogens, are produced during curing, frying and some salting and pickling processes. Ethyl carbamate can be produced during fermentation and is found in beer and distilled spirits, particularly Scotch whiskeys. Chloropropanols may result from the hydrolysis of proteins with hydrochloric acid. The food industry is gradually reducing the levels of these contaminants. Some countries prohibit traditional smoking processes; many manufacturers use a liquid smoke flavour that is free of polynuclear aromatic hydrocarbons.

Unlike contaminants, additives are put in food intentionally. When used properly, they protect food from spoilage and from pathogenic organisms, thus helping to ensure a plentiful and diverse food supply. At the same time, some may be hazardous if used excessively.

Other food additives may be dangerous if too little is added to food. For example, nitrite is used to prevent *C. botulinum* spores from growing in cured meat products, but a minimum residual level is necessary to ensure its effectiveness. Insufficient iodine in salt can give rise to iodine deficiency disorders.

Some food additives (e.g. sulphite) may provoke allergenic responses. People with metabolic deficiencies may react to certain additives as well as to the food. Accurate and complete food labelling helps these consumers to avoid products which could harm them.

The additives use in food are :

- Anti-caking agents
- Antimicrobial agents
- Antioxidants
- Colours
- Curing and pickling agents
- Emulsifiers
- Enzymes
- Firming agents
- Flavour enhancers
- Flavouring agents
- Humectants
- Leavening agents
- Release agents
- Non-nutritive sweeteners
- Nutrient supplements
- Nutritive sweeteners
- Oxidising and reducing agents
- pH control agents
- Propellants and gases
- Sequestrants
- Solvents and vehicles
- Stabilisers and thickeners
- Surface-active agents
- Texturizers

3.3. Agricultural contaminants

Most countries require agrochemicals to be registered, with information on safe conditions for use. This information is often provided on the product label. Usually, a waiting period is needed between use of the agrochemical and harvest or slaughter. If the agrochemical is not applied properly or if the waiting period is not observed, hazardous residues may remain in the food.

Chemical agricultural inputs are heavily promoted in many developing countries as a way to raise crop yields. In these countries, the farmers may not be trained in the proper use of the chemicals. Organochlorine pesticides banned for use on crops, such as DDT, are used illegally on food. Data collected by the GEMS/Food Programme, while not comprehensive, indicate that pesticide misuse can become a problem if monitoring and control programs are not in place. Chemical agricultural which may risk as food contaminants as the following.

- Insecticides : organochlorine insecticides organophosphorus insecticides, and carbamate insecticides
- Animal Drugs : antimicrobials, growth promotants, anthelminthics, and therapeutics
- Other agrochemicals : Fumigant, fertilizers, nematocides, fungicides, plant growth regulators, molluscicides, herbicides and rodenticides.

3.4. Other Chemicals

Few countries regulate the use of all chemicals (indirect food additives) that may leave residues in food, such as processing aids and cleaning agents. Chemicals can migrate from materials in contact with the food; for example, from packaging. In many countries, the specifications for food-grade plastics include limits on extractable materials.

Contaminants may be transferred from cookware or containers. Cooking acidic food in a copper-lined pot can introduce copper into the food. Lead may be transferred to food from certain ceramics, and food in lead-solder cans has significantly higher lead levels than food in cans with welded seams.

Table 9. Sources of Chemical Contaminants

Material	Source
processing aids	ion-exchange resins, filter aids enzyme preparations microorganisms solvents, lubricants, release agents specific function additives
food contact materials	utensils working surfaces equipment
packaging materials	metal, plastic, paper, wood
cleaning agents	detergents sanitizers

Adulterants are used to deceive the consumer as to the quality or value of the product. Sometimes, they are dangerous. For example, borax and boric acid were once widely used as low-cost food preservatives, but are now judged to be too toxic. In developing countries, however, they are still used illegally. Similarly, formaldehyde is sometimes used to preserve fish and other seafood, especially in places where adequate refrigeration is not available.

The most common adulterant is water, which is added to foods such as milk, fruit juices and seafood. If the water is contaminated, it may harm the consumer.

In some developing countries, the use of textile dyes in food, many of them carcinogenic, is a serious problem. Street-food vendors use them because they are cheap and readily available. Most consumers are unaware that these dyes are dangerous.

Chemical hazards at home:

- metal cookware contaminated with heavy metals
- ceramic or enamelled serving dishes with toxic glazes
- leaded crystal used with acid foods
- copper pans and utensils
- miscellaneous home-use chemicals

Consumers usually cannot detect chemical contaminants, so they and their advocates must work to strengthen government monitoring to assure the safety of their food and drinking water.

Consumers can also take steps to reduce their risks. For example, washing removes pesticide residues from fruits and vegetables. They can avoid cookware that is made of material that might contaminate the food. They can take proper safety measures when using strong cleaning materials to be sure they do not enter the food.

Food processing can affect the availability of minerals. Removing bran during flour milling can help to increase the absorption of the iron (phytates found in bran can inhibit iron absorption). Heat treatment may reduce the vitamin C content of foods thereby decreasing iron availability (vitamin C promotes iron absorption). Fermentation and germination increase the absorption of iron (non haeme). Mild heating may increase the availability of some minerals while high heating temperatures may decrease their availability. Addition of phosphates may reduce the availability of calcium, iron and zinc.

Some processes *may increase* the nutrient content of foods e.g. during storage the zinc, copper and iron content of canned foods may increase due to contamination from the can.

Much of the *mineral loss* during processing is due to physical removal; e.g. milling of flour reduces zinc, iron, magnesium and calcium content. Some minerals, such as potassium and sodium, are water soluble and can leach into cooking water. The levels of zinc, copper and iron in meat may be reduced due to shrinkage during cooking.

Loss of vitamin and mineral contents. Vitamins can be sensitive to heat, water, oxygen and light - different vitamins are sensitive to different factors. Fat soluble vitamins are less sensitive than water soluble vitamins. Folate, B1 and C are sensitive to heat and easily lost in cooking water. The losses of water-soluble vitamins increases with the quantity of cooking liquid. Vitamin C is water soluble, easily destroyed by heat and with alkaline or neutral pH. Thiamine is most heat labile at a pH of 7. Because vitamin C, folate and thiamine are so sensitive, they are used as indicators of the effect of food processing. Milling flour and rice can lead to high losses of all B vitamins through physical removal.

Some processes *may increase* the nutrient content of foods e.g. B1 increases with fermentation. When evaluating nutrient losses during food processing, it is important to consider the contribution of the food to the diet. If the food is an important source of a nutrient then it is essential to minimise losses of the nutrient (or even fortify to replace the nutrient(s) lost during processing). For example, in countries where milk is not an important source of vitamin C, losses of vitamin C from milk are not as important as losses from available good vitamin C sources such as fruits and vegetables.

'Fresh food is the best food' is not necessarily true. Frozen vegetables retain more nutrients after cooking than canned or fresh vegetables, because they are frozen immediately after picking (nutrient losses increase with time after the fruit or vegetable is harvested). It is therefore important to look at the overall losses of nutrients at each stage from fresh to processing to storage to preparation to table.

Macronutrients (carbohydrates, protein and fat) are relatively stable to food processing. Treatments such as flour milling physically remove fat, protein and fibre (and vitamins and minerals) and increase the amount of carbohydrate (starch). Heat treatments such as blanching (freezing), pasteurisation and sterilisation (for bottling and canning) can denature proteins. Proteins may react with reducing sugars in foods, causing Maillaird reactions e.g. in bread baking, milk processing and making breakfast cereals. As a result some amino acids, in particular the essential amino acid lysine, cannot be used by the body to make protein. Fats can be oxidised and degraded in the presence of heat and oxygen. The carbohydrate content of some foods is increased during processing e.g. by adding sugar as a preservative.

Allergens. *Food allergy* is an immunologically-based adverse reaction to a food protein. Reactions can occur in the presence of a wide range of concentrations of the allergen, and the thresholds for reaction are generally unknown. Thus, it is difficult to define safe levels of exposure to food allergens for sensitised individuals.

Food intolerance is an adverse reaction to a food component that is neither immunologically nor psychologically based.

There is a spectrum of mechanisms responsible for food intolerance, including pharmacological and metabolic effects. Sulphite and biogenic amines have frequently been associated with severe reactions. These reactions are "idiosyncratic" because we do not know what the mechanisms are.

Allergens of codex list:

- Barley, oats, wheat, triticale and their products (gluten and starch included)
- Crustaceans, shellfish and their products
- eggs and egg products
- Fish and fish products
- Legumes, peas, peanuts, soybeans and products of these
- Milk and milk products (including lactose)
- Sulphite in concentrations of 10mg/kg or more
- Tree nuts and their products

Manifestations of food allergy range from eczema, oral and gastrointestinal disturbances to asthma and anaphylaxis. Gastrointestinal disturbances may lead to nutritional deficiency and reduced quality of life. More severe reactions include swelling of the larynx and vocal cords, an asthma-like wheeze and falling blood pressure. Reactions that include or exceed laryngeal swelling are classified as anaphylactic reactions and are medical emergencies. Anaphylaxis can be fatal, but cases related to food are rare (approximately 3 cases per million people per year). Reactions may be triggered by extremely small amounts of allergen, e.g. allergic reactions to peanuts can be triggered by very small traces of nut protein, while individuals allergic to fish have been reported to react to aerosolised protein generated during cooking. Some airlines no longer serve peanuts because peanut dust may cause anaphylaxis in sensitive individuals.

Many cases of accidental exposure to allergens are due either to mislabelling or to cross-contamination.

Preventing food allergens in the food industry through:

Main controls for the food industry

- ensure that ingredient listings are accurate, indicating all components of the product
- minimise potential for cross-contamination and mislabelling

Food processing

- ensure that the design and installation of equipment allows easy, adequate cleaning
- minimise the chances of cross-contamination by ensuring good manufacture layout (e.g. dust from peanut operations)
- include allergens in HACCP studies

Planning of food production

- produce products containing allergens last in a production run to minimise chance of cross-contamination
- clean thoroughly between formulation changes
- ensure availability of correct packaging, which accurately lists the ingredients

Cleaning

- keep equipment clean to minimise potential for cross-contamination
- clean the production line thoroughly after producing a product containing allergens
- ensure that cleaning procedures are available and up to date

Labelling and packaging

- ensure that the label gives an accurate description of the product formulation
- ensure that the label is used on the correct product
- ensure that labels are updated when formulation changes are made

Physical hazards. Food can be contaminated with foreign material that could be a physical hazard to the consumer. Any hard object can damage teeth or choking when swallowed. These often pose a high risk for young children. Potential physical hazards reported as a piece of:

- Glass
- Metal
- Bone
- Plastic
- Stones and rocks
- Capsules or crystals
- Pits or shell
- Wood
- Paper
- Human and animal hair

Few statistics are available on physical hazards in food. These problems tend to be under-reported or reported only to the food manufacturer.

Soft drinks are most frequently implicated in injuries, usually lacerations, although this may be due to the high number of units consumed (thousands of millions in the US). The high ranking of infant foods may be due to differential reporting rates, as parental concern raises "outrage" levels. Laceration is the most common injury, followed by gastrointestinal distress, and then damage to teeth and fillings. Note that the largest category of food is "others," indicating the low-level, widespread occurrence of this problem.

4

4 TECHNOLOGIES TO CONTROL FOODHAZARDS

Humans have been dealing with food for centuries. With the development of their knowledge by learning and observing, they found ways of preserving raw food that had been collected by cultivation and or hunting. Some early ways of preservation that was done traditionally were dried under the sun, salted and dried, stored in cool caves, frozen at high latitude and altitude, dried-smoked over fires, and fermented. Usually, foods that were preserved were source of carbohydrates, and protein such as meat, fish, fruits, vegetables.

Table 10. Example of Traditional Food Preservations

No	Preservation	Food
1	Dried under the sun	Tomato (Italy)
2	Dried-salted	Salted Fish (Indonesia), meat (South Africa)
3	Dried-smoked over fires	Meat (Indonesia), Kipper-smoked herring (UK)
4	Stored in cool caves	Fruits, vegetables
5	Frozen	Meat (Switzerland), potato (Peru)
6	Fermentation	Tempe- fermented (Indonesia), tape-(fermented rice, fermented cassava) cheese, wine, sake, beer, yoghurt

4.1. Factors leading to microbial foodborne illness

Foodborne illnesses occur from the mild symptoms such as headache to severe symptoms such as fainting and even death. In microbial foodborne illness, we deal with living organisms where they could take effect when the quantity is enough to affect the body. Furthermore, to reach its effect, microorganisms need good temperature, time, pH and water activity to grow. Hence, if microorganisms have the 4 factors in the food, it is most likely that people who consume the food will experience foodborne illness.

Foodborne illness caused by microorganisms can manifest in broad spectrum conditions, ranging from relatively mild and self-limiting to severe condition resulting in morbidity and mortality. Some groups of people are more vulnerable to foodborne illness, thus high morbidity and mortality can occur in these groups called "YOPI" which include the Young (infants), Old, Pregnant women, and Immunocompromised people.

Many factors can lead to foodborne illness, such as from **unsafe sources food, inadequate cooking, improper holding temperature, contaminated equipment and cross-contamination of foods, and poor personal hygiene.**

Food from unsafe sources. Purchasing foods from suppliers that are not practicing food safety may lead to foodborne illness, particularly for foods that will not be processed further or have minimum processing before consumption, such as raw fruit and vegetables salad, unpasteurized milk, and raw beansprouts. Foods that are consumed raw will not receive processing that can kill or reduce microorganisms. Therefore, having approved source is important.

However, even the foods that need to be cooked before consumption may still cause foodborne illness. In order to reduce the risk, checking the food when receiving may help. Foods with broken packaging and swollen or dented cans, sign of pest contamination, passed use-by date/ expiration date, improper labelling, or improper storage must be avoided.

Inadequate cooking. Many raw foods, especially meats contain bacteria microflora can be pathogenic. To eliminate or reduce the number of the pathogenic bacteria, cooking is the only option. Proper cooking temperature and time is critical to inactivate the vegetative cells. The proper temperature must reach all parts of the food, not only the surface. In this case, adequate thawing before cooking is also important. Adequate thawing ensures all part of the food is thawed or melted. Thus, adequate cooking is easy to be done. to ensure that all part of the food is reached the same temperature, an accurate food thermometer is necessary used.

Tables 11. Adequate Time and Temperature for Adequate Cooking

Food	Temperature	Time at Specified Temperature
Meat, egg, seafood, whole poultry, soups	70 °C	-
Burgers, poultry livers	70 °C	≥ 2 min
Corned beef, ham	60-70 °C	85 s
Stuffed fish, stuffed pasta, stuffed poultry	74 °C or above	15 s

Improper holding temperature. Raw foods may contain not only vegetative cells of pathogenic bacteria, but also heat resistant spores which may survive the cooking process. After cooking, foods that are not eaten immediately should not be kept in room temperature for prolonged time and slowly cooled. The foods must be cooled within two hours from 57°C to 21°C and within 6 hours to reach 5°C. Prolonged cooling temperature/time allows the spores to germinate into vegetative cells which can multiply rapidly and cause foodborne illness. Then, foods should be stored in low temperature at <5°C to supress the growth of the microorganisms, even though there are microorganisms that can still grow slowly at refrigerator temperature, like *Listeria monocytogenes*.

Contaminated equipment and cross-contamination of foods. Inappropriate cleaning of kitchen utensils and food contact surface allows the food residue to build up. This is a suitable condition for bacteria to grow, multiply, and contaminate foods that are in contact with it. Therefore, in order to prevent this, the utensils and food contact surface should be cleaned thoroughly and regularly.

Raw foods and ready-to-eat foods should be separated and not in contact. Different utensils, e.g knife, chopping board, need to be used for raw and cooked foods. In the refrigerator, the raw foods have to be placed below the ready-to-eat foods to prevent possible leaking or dripping from the raw foods that may lead to cross-contamination.

Poor personal hygiene. Food handlers should maintain good personal hygiene in order to prevent food contamination. Food handlers may contaminate foods with bacteria, not only from the environment but also from their own body's *microflora*, e.g *Staphylococcus aureus*. The food handlers that suffer from coughing, sneezing, gastrointestinal illness or show some symptoms should be restricted from contacting with foods until they have fully recovered since it is possible that the illness may spread to the consumers through the foods they are prepared and causing outbreak. Food handlers infected by *Salmonella* Typhii, Hepatitis A virus, Norovirus, *Shigella* spp., Enterohaemorrhagic or shiga toxin producing *E. coli* should be excluded from the food facility for weeks or more. Moreover, there are some do's and don'ts of personal hygiene for food handlers as the following.

Table 12. Personal Hygiene Practices for Food Handlers

Do	Don't
Properly and regularly wash hands, especially: • when you first arrive at work and enter the kitchen • after using the toilet • after sneezing, coughing, or blowing the nose • after touching any parts of the body (e.g hair, face) besides your hands • after handling raw foods • after performing non-food preparation related activity, like handling waste or chemicals, eating, washing dirty utensils, using phone, or handling money	Do not smoke, chew gum, or fingernails Do not taste food Do not spit, sneeze, cough over food Do not pick nose, ears or any body parts Do not wear jewellery during food handling Do not wear protective clothing outside the processing area
Keep fingernails clean and short	
Bandage and cover any cuts, sores, or open wounds and the food handlers must wear gloves	
Keep hair clean and covered	
Wear clean protective clothing in food processing area	

4.2. Factors influencing the growth and survival of microorganisms in foods

Foods provide suitable environment for microorganisms to grow. Microorganisms in foods not only come from its normal flora, but may also be introduced from outside during planting/growing, harvesting/slaughtering, processing and storage. The interaction among flora and introduced microorganisms may enable the microorganisms grow together (association) or prevail the others (succession). The microbial composition will change continuously.

The factors affecting the growth of microorganisms in foods will determine the foods spoilage and potential foodborne illness. They may also determine whether specific food requires time/temperature control along the food production chain to assure consumer protection. The factors are classified into four groups based on physicochemical properties of the foods (intrinsic factors), environment conditions (extrinsic factors), properties and interactions among microorganisms in the food (implicit factors), and processing factors.

Intrinsic factors

Nutrient content. Foods contain nutrients that can be utilized by microorganisms to grow. The nutrients required are those that can act as the source of energy, carbon, and other materials which include water, energy source, nitrogen, vitamins, and minerals. Different type of foods contains different nutrient composition. Meats are rich of protein, lipids, mineral, and vitamins but low levels of carbohydrates. Otherwise, plant-based foods contain high level of various carbohydrates and range concentration of proteins, minerals, and vitamins.

The predominant microorganisms in foods are determined by their ability to utilize nutrients present. The inability of a microorganism to synthesize a major component of a food will limit its growth. The growth rate is limited by the concentration of essential nutrients in foods. The Monod equation describes the relationship between the two:

where μ is the specific growth rate; μ_m is the maximum specific growth rate; S is the concentration of limiting nutrient; and K_s is the saturation constant. When the value of S is much higher than K_s, a microorganism will grow approaching its maximum rate, vice versa. Foods contain abundant nutrients in which they support the growth of various foodborne pathogens. Therefore, it is unfeasible to predict the growth of the pathogens based on nutrient content in food.

pH and buffering capacity. The microbial cell is composed of various macromolecules, such as enzymes which are important for growth and metabolism of the cell. The activity and stability of macromolecules is affected by the pH of the environment. The pH within the cell must be within the optimum range to have optimal growth. Commonly, bacteria grow optimally in the pH of 6.0-8.0, yeasts 4.5-6.0 and filamentous fungi 3.5-4.0, and pathogens are not able to grow or grow slowly at pH levels below 4.6; but there are exceptions.

Increasing food acidity either through fermentation or addition of weak acids, has been used for food preservation. Most foods are slightly acidic in their natural state since alkaline pH has unpleasant taste. Only a few foods have alkaline PH, for instance egg and fermented shark. The acidity of the foods can affect the microbial ecology and spoilage character. For instance, low pH in fruits can inhibit the growth of bacteria, therefore the spoilage is dominated by yeasts and fungi. Another important food characteristic to consider when using acidity as a control mechanism is its buffering capacity, a capacity to maintain its pH. Foods with low buffering capacity may change pH quickly when exposed to compounds secreted by microorganisms.

Table 13. pH Range of Animal and Plant Products

Food	ph Range
Dairy products	
Milk	6.3-6.5
Cheese	4.9; 5.9
Yoghurt	3.8-4.2
Meat and poultry (and products)	
Beef	5.1-6.2
Chicken	6.2-6.4
Fish (most species)	6.6-6.8
Fruits and vegetables	
Apples	2.9-3.3
Apples cider	3.6-3.8
Bananas	4.5-4.7
Oranges	3.6-4.3
Watermelons	5.2-5.6
Carrots	4.9-5.2; 6.0
Corn	7.3
Spinach	5.5-6.0
Broccoli	6.5

Redox potential. An oxidation-reduction (redox) reaction occurs as the result of electrons transfer between atoms or molecules. Thus, redox potential (E_h) is measured by the tendency a substance gains or loses electrons. In living cells, redox reaction is essential to generate energy by oxidative phosphorylation. Several factors may influence the measured E_h in foods, such as redox couples present, ratio of oxidant to reductant, pH, oxygen availability, and microbial activity. Redox potential affects the composition of microflora in food. There are microorganisms which can only grow on a specific redox range. Obligate aerobes require oxygen and high E_h to generate most of their energy by oxidative phosphorylation. Therefore, they will predominate the food surface where oxygen is abundant. On the other hand, obligate anaerobes tend to grow at low or negative redox potential and need the absence of oxygen. They pose a risk since they grow deep in the meat tissues, in vacuum packs, and canned foods causing spoilage.

Water activity. The amount of water in liquid state available for microorganisms to be able to grow in food products is called water activity (a_w). Most of the fresh foods contain a_w at the optimum range for most microorganisms to grow (0.97-0.99). Controlling the moisture content may prolong the shelf-life of the foods. The a_w can be controlled by increasing concentration of solutes (salt or sugar), physical removal of water through baking or drying, or binding of water to macromolecules in the food. With decreasing water activity, the osmotic pressure is increased, not only in the environment but also in the cytoplasm of the cell. Thus, the number of groups of microorganisms capable to grow decreases. In general, Gram (-) bacteria are more sensitive to low a_w than Gram (+) bacteria. For example, jelly is a food product with high moisture content but low water activity. The jelly contains sugar that lowers the water activity and therefore decreases the amount of water available for microorganisms to grow.

Table 14. Water Activity Minimum of Microorganisms Growth

Microorganism	Minimum a_w
Group of microorganism	
Most Gram negative bacteria	0.97
Most Gram positive bacteria	0.90
Most yeasts	0.88
Most filamentous fungi	0.80
Halophilic bacteria	0.75
Xerophilic fungi	0.61
Toxigenic mould	
Aspergillus ochraceus	0.78
Penicillium verrucosum	0.79
Aspergillus flavus	0.80
Fusarium moniliforme	0.87
Stachybotrys atra	0.94

Table 15. Water Activity of Animal and Plant Products

Food	a_w
Animal Products	
Fresh meat, poultry, fish	0.99-1.00
Natural cheeses	0.95-1.00
Eggs	0.97
Cured meat	0.87-0.95
Sweetened condensed milk	0.83
Honey	0.75
Plant Products	
Fresh fruits, vegetables	0.97-1.00
White bread	0.94-0.97
Baked cake	0.90-0.94
Jam	0.75-0.80
Flour	0.67-0.87
Dried fruit	0.55-0.80
Cereal	0.10-0.20
Sugar	0.19
Crackers	0.10

The microorganisms that are able to grow in low water activity divide into three different groups based on the types of foods:

a. Halotolerant – able to grow in high concentration of salt
b. Osmotolerant – able to grow in high concentration of sugar
c. Xerotolerant – able to grow on dry foods

The limiting value of water activity for microbial growth is ca. 0.6 whereas below this number the spoilage of foods is mostly due to insects or oxidation.

Antimicrobial barriers and constituents. All foods naturally contain antimicrobial components and compounds since they come from parts of living organisms which have natural protection from microbial infection. A physical barrier, such as skin, shell, husk or rind, generally consists of macromolecules that are resistant to degradation and having hostile environment for microbial growth by having low water activity, limited readily available nutrients, and antimicrobial compounds. Physical damage of this physical barrier may accelerate the deterioration of the foods since microorganisms can penetrate to the nutrient-rich part of the foods.

Besides the physical barrier, the product tissues may contain antimicrobial compounds. There are two types of antimicrobial compounds based on their nature of work, which are:

a. *Microbistatic*, inhibiting the multiplication of microorganisms
b. *Microbicidal*, killing microorganisms

The compounds may attack different parts of the microorganisms, such as the cell structure (cell wall, cytoplasmic membrane), microbial enzymes (oxidative agents, chelating agents), or microbial DNA.

Many plant tissues components, like in herbs and spices, have antimicrobial properties. Therefore, the usage of herbs and spices may contribute to the microbiological stability of the foods and hindering the spoilage. Animal products, such as egg and milk, also have antimicrobial compounds. Milk and the albumen of the eggs contains lysozyme that weaken the rigidity of bacterial cell wall. Egg white also has a component that scavenge iron from the medium in which it may limit the growth of microorganisms.

Extrinsic factors

Relative humidity. Relative humidity is interrelated to water-activity, thus relative humidity is a measure of the water-activity of the gas phase. When the food commodity having low water-activity is stored in an open air with high relative humidity, water from the gas phase in the environment will transfer to the food. Even though it takes time for the food to increase in water-activity, condensation may occur on food surface and create a localized area of high water-activity. This condition will favour the viable spores and cells present in food to germinate and grow. Once the microorganisms have started to grow and become physiologically active, they may contribute in increasing water-activity of the food from the result of their respiration. The increasing water activity of the food will allow other microorganisms that need high a_w to be able to grow and cause spoilage in a food that was initially unsupported the microbial growth and considered to be microbiologically stable.

Temperature. Microorganisms are able to grow in temperature ranging from -8 °C to 100 °C. However, no microorganism can grow over the whole temperature range. They have minimum, optimum, and maximum temperature at which growth can occur, known as cardinal temperature. The cardinal temperature of a microorganism is affected not only by the characteristic of the microorganism, but also nutrient availability, pH, and a_w. Regarding the cardinal temperature, microorganisms can be categorized into several groups as mentioned in the table below.

Table 16. Categorization of Microorganisms Based on Cardinal Temperature

Group	Temperature (ºC)		
	Minimum	Optimum	Maximum
Thermophiles	40-45	55-75	60-90
Mesophiles	5-15	30-40	40-47
Psychrophiles (obligate psychrophiles)	-5 to 5	12-15	15-20
Psychrotrophs (facultative psychrophiles)	-5 to 5	25-30	30-35

At low temperature below cardinal temperature, microbial growth will stop due to slower reaction rates of the enzyme and reduce the fluidity of the cytoplasmic membrane. At high temperature above cardinal temperature, denaturation of cell components and inactivation of heat-sensitive enzymes occur.

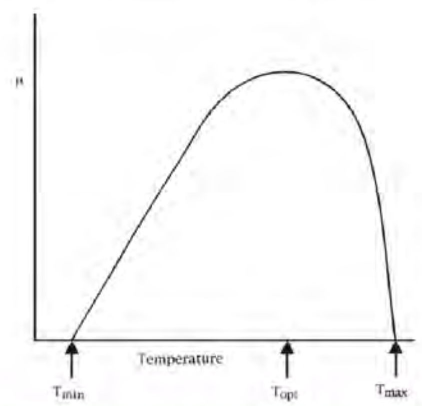


Figure 8. Microbial Growth and Temperature

At low temperature below cardinal temperature, microbial growth will stop due to slower reaction rates of the enzyme and reduce the fluidity of the cytoplasmic membrane. At

high temperature above cardinal temperature, denaturation of cell components and inactivation of heat-sensitive enzymes occur.

In food safety, mesophilic and psychrotrophic microorganisms are in paramount concern. Mesophiles are frequently of human or animal origin and able to grow optimally at temperature ca. 37 °C. When foods are stored in mesophilic environment, the mesophiles will grow faster than other microorganisms and spoil the foods.

When foods are stored at low temperature, such as in the fridge, psychrotrophs and psychrophiles are the two groups that are in concern. Psychrophiles will grow better than psychrotrophs at low temperature, however psychrotrophs have wider range of cardinal temperatures. This means psychrotrophs can be found in more diverse habitats, therefore they become greater importance in the spoilage of chilled foods.

Gaseous atmosphere. The atmosphere is composed of 21% oxygen which foods are mostly in contact with. It influences the redox potential on microorganisms thus affecting their growth rate. However, the atmosphere contains other gases besides oxygen that can be utilized to control microbial growth. There are two mechanisms on how gases inhibit microbial growth, which are by:

1. Having direct toxic effect on growth of certain microorganisms.
   Ozone (O_3) and oxygen (O_2) are highly toxic to anaerobic bacteria by generating oxidizing radicals. Carbon dioxide (CO_2) is effective in deterring the growth of obligate aerobes.
2. Modifying gas composition of the environment which have indirect inhibitory effect.

Various technologies in modifying gas composition present nowadays for instance modified atmosphere packing (MAP), controlled atmosphere packaging (CAP), direct addition of carbon dioxide (DAC), and hypobaric storage. These methods can prolong the shelf life of foods and has been applied to fruits, vegetables, raw beef, chicken, fish, dairy foods, and ready-to-eat foods.
CO_2 is commonly used in MAP and DAC for carbonated drinks. CO_2 in low temperature has higher solubility in foods, hence can lower the pH of the foods. It is effective against moulds and oxidative Gram negative bacteria, but not to Gram positive bacteria. Nitrogen (N_2) are commonly used in MAP to replace oxygen, thus having indirect inhibitory effect on aerobic bacteria.

The major concern for safety reason of modified gas composition technologies is the loss of sensory cues to spoilage. Without spoilage bacteria indicators, the food could have acceptable organoleptic quality, but may be unsafe due to the ability of facultative and obligate anaerobic pathogens that can grow in the limitation or absence of oxygen.

Implicit factors

The properties of the microorganisms themselves determine how they respond to the environment and interact with others. Each microorganism has their own specific growth rate which can define the predominant microflora in food. Those with the highest specific growth rate will dominate over time. Many moulds are able to grow on fresh foods, like meat and fish, however they are outcompeted by bacteria since they grow slower. In foods with unfavourable conditions for fast growing bacteria, mould could play an important role in causing spoilage. If two microorganisms have the similar specific growth rate, the difference in affinity for a growth limiting substrate will determine growth. Microorganism with higher affinity will outgrow the other.

However, the fast-growing microorganisms are more susceptible to and easier to be killed by heat, low pH or antimicrobials than the stationary phase cells or slower growing microorganisms. At higher growth rates, the cell activity is greater, thus the damage caused by slight shock to the system will be more severe than the same disruption in slower growing cells.
Microbial interaction also plays an important role in determining the growth and survival of the cells. There are three kinds of interaction that may occur among microorganisms, such as:

1. **Mutualism** – the growth of one microorganism stimulates the growth of others. For example, in yoghurt fermentation, *Streptococcus thermophilus* will consume the lactose from milk and convert it into lactic acid and creating acidic environment. This condition supports the growth of *Lactobacillus acidophilus* that will produce exudates contributing in forming yoghurt flavour. Growth of *S. thermophilus* is limited to by the availability of peptides and free amino acid in which *L. acidophilus* liberates those compounds and support the growth of *S. thermophilus.*
2. **Commensalism** – one microorganism is benefited while others is neither benefited nor harmed. For instance, in tape fermentation, *Saccharomyces* utilize the glucose from the cassava and secreted alcohol that is not beneficial for it. However, the alcohol produced is the main food source for *Acetobacter* that will be converted into acetic acid which creates acidic flavour of the tape.
3. **Antagonism** – one microorganism may produce compounds that are inhibitory to other microbial population. For example, *Lactococcus lactis* produces bacteriocin called nisin that may inhibit the growth of Gram positive bacteria in cheese-making.

Processing factors

Slicing. Slicing will damage physical barrier of the food products and expose the microorganisms into nutrient-rich components.

Washing. Washing foods may reduce the number of microflora. However, if water used for washing the foods contains pathogens, then the foods may also get contaminated.

Irradiation. Irradiation of foods commonly uses two types of spectrum, namely microwaves and UV. Microwaves act indirectly to the microorganisms through the production of heat. When a food containing water is placed in a microwave fluid, the water molecules are continually wavering, leading to a rapid rise in temperature throughout the product. However, the drawback of using microwaves is the presence of cold spots which means uneven heating. This increases the concern over the risks related to consumption of inadequately heated foods. UV radiation could induce photochemical reactions in microorganisms that will cause the failure of critical metabolic processes leading to injury or death. The wavelength that shows highest mortality is around 260 nm which correspond to a strong absorption by nucleic acid bases. Some microorganisms have the ability to repair the damage caused by UV radiation in which viruses become the most resistant and followed by mould spores and bacterial spores.

Pasteurization. Pasteurization is a heat process between 60-80°C up to a few minutes to eliminate pathogens and spoilage microorganisms. Not all microorganisms can be eliminated through this process, especially the thermophiles. They can grow and spoil the foods; therefore, low temperature storage is essential for an acceptable shelf life.

5

5 GOOD HYGIENIC PRACTICES

5.1. Food hygiene

Food Safety practices lay from farm to table. The good practices and establishment of operating procedure should be taken to ensure that food preparation is not disturbed by the environment. Generalized from Codex "General Principle of Food Hygiene", Good Hygienic Practices defined as all practices concerning conditions and measures to ensure the safety and suitability of food at all stages of the food chain. Therefore the phrase "food should not only be safe", means that the food shouldnot cause harm and also suitable, meaning that food is acceptable to be consumed according to its intended use.

Food hygiene is related with contaminants. Contaminant is any biological or chemical agents, foreign matters or substances that are not intentionally added to food which may affect safety and suitability of the food. GHP has a role to prevent, and eliminate the occurrence of contaminant to acceptable levels at any process from raw materials, food production as well as environment.

Other aspect related with food hygiene is cleaning and disinfection. Cleaning is very important to be conducted in GHP. It removes soil, food residue, dirt, dust, waste, grease or other materials from surfaces. Once cleaned, some surfaces need to be disinfected using physical or chemical substances which removes or eliminates most pathogenic microorganisms. Chemicals used in disinfection are called disinfectants. Some chemicals used as disinfectants are chlorine, chlorine dioxide, ozone, ultraviolet light, while physical methods are heat treatment, coagulation, flocculation, sedimentation, and filtration.

There are 8 general area to ensure food hygiene and should be combined with other specific guidelines. Effective implementation of these principles could prevent consumer from food borne disease, spoilage or adulteration.

1. Primary production

Preventing food contamination from contaminants should be initiated from the stage where the food is produced or collected. Pesticide residue in vegetables, and availability of *E.coli* or *Salmonella* in poultry may become contaminants based on critical limit of availability in the product. Other examples are antibiotics, or microorganisms that could arise in food, which is even dangerous when eaten raw. Hygienic practices at primary production help reduce the likelihood of hazard occurrences which may be difficult to be controlled at the later stages of the food chain.

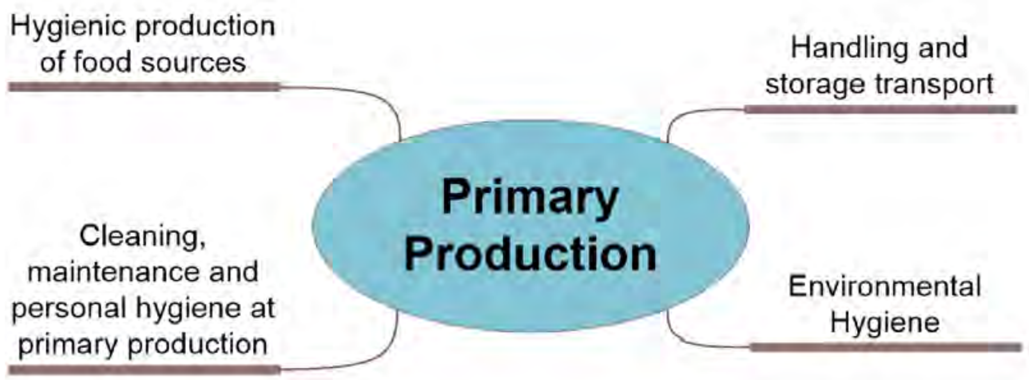


Figure 9. Scope of Primary Production

2. Design and facilities establishment

All establishments including buildings or premises, surfaces, facilities and equipment should be planned well for safety purposes. Selecting location, building design, construction and lay out should be designed to prevent final product from contamination as well as protection against pests. Pest control is important to be considered since they are sources of microbiology contamination. Selecting location for food establishments should consider air pollution condition, flooding area, natural pest occurrence.

Facilities establishment covers water, lighting, storage and air. Water that are used should be potable water and sufficient for production processing, personal hygiene and toilet requirements. Water management is an example which indicates whether a facility's water flow is running well or not. It manages water from input, usage to waste.

Lighting facilities should be sufficent to enable personnels to see clearly. Further more, lighting materials should be unbreakable or covered by a protector to prevent harm and contamination if breakage occurs. Storage facilities should be designed to prevent cross contamination as well as protection from any pest manifestation.

Air quality, ventilation, humidity, and air temperature are associated with the quality of products. Food products could be easily spoiled by high humidity of environment or air temperature. Hence, controlling the air condition of the facilities is very important in preventing quality of the products.

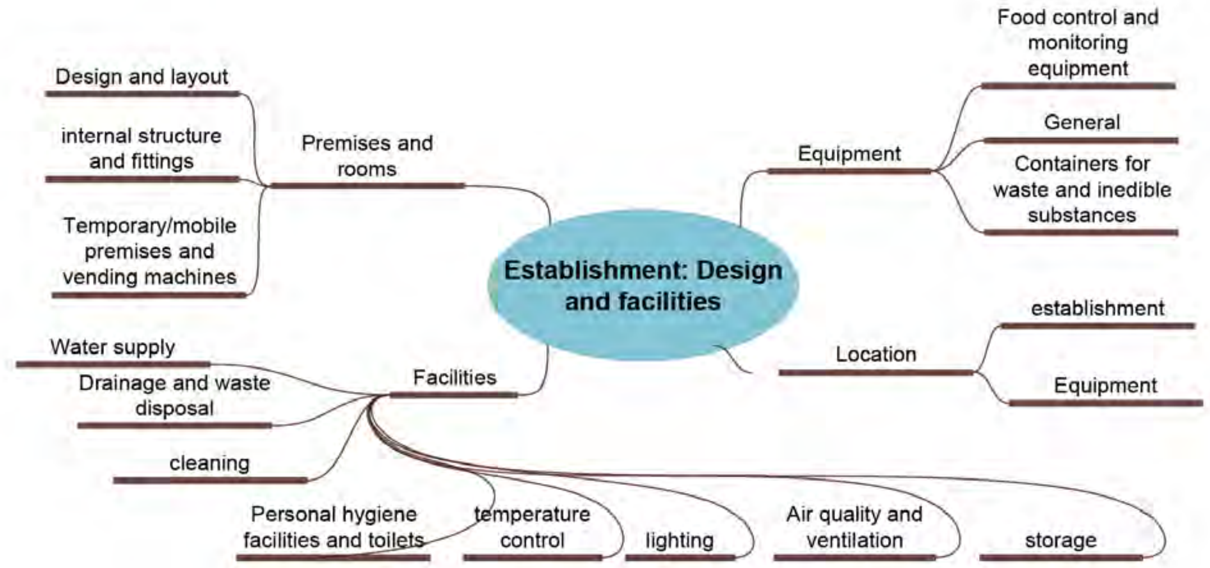


Figure 10. Scope of Establishment: Design and Facilities

3. Operation control

Controlling operation of an industry or manufacturer relies on management. All hygiene practices have a specific procedure to ensure that it is well implemented and effective, thus requiring a control system which is documented and recorded. One example, there are some indicators developed to know whether or not cleaning has been done effectively, e.g. no physical hazard occurs. To ensure that the objective is achieved, cleaning schedule documentation should be developed to check or validate whether the procedure is well conducted or not.

Figure 11. Scope of Operation Control

4. Establishment of maintenance and sanitation

Maintenance of all facilities is essential in every food industry to ensure all facilities are running as it functions and to prevent contamination of product from hazards such as debris, soil, residues, metal shards and other substances. Cleaning activities can be performed by physical methods using water or non-water, chemical method or the combination of both. Physical method by using water includes scrubbing, heating, and high-pressure water flowing, while the non-water method includes heating and vacuuming. Chemical methods use detergents, acid or alkalis. It works by binding substances chemically followed by water cleansing.

Maintenance activities involves checking, servicing, repairing, replacing required devices in all infrastructures of the manufacture, including building, machinery, electricity, waste management, etc. A good maintenance program enables the team to detect any failure at an early stage and thus could prolong active periods of facilitites. Proper maintenance could also support production because all the equipments, including machineries, are always ensured to be in optimum condition.

The key factor of both maintenance and sanitation program is routine effective monitoring. For these two programs, a written regulation which includes scheduling is required so that the program can be performed.

Besides hazards, pests definitely should be avoided from the food production area. The building design is the first step in preventing pest and pest infestation. However, other preventive programs are necessary to be performed in food industries. Programs that could be established for pest management is hiring employees for the specific task. Another example is through outsourcing or offering the job to pest management professionals. The main objective of pest management is to prevent the presence of pestsand to ensure that there are no pest infestation around the manufacture. The occurrence of pests is one indicator of the effectiveness of the program and it needs to be conducted regularly to maintain its effectiveness.

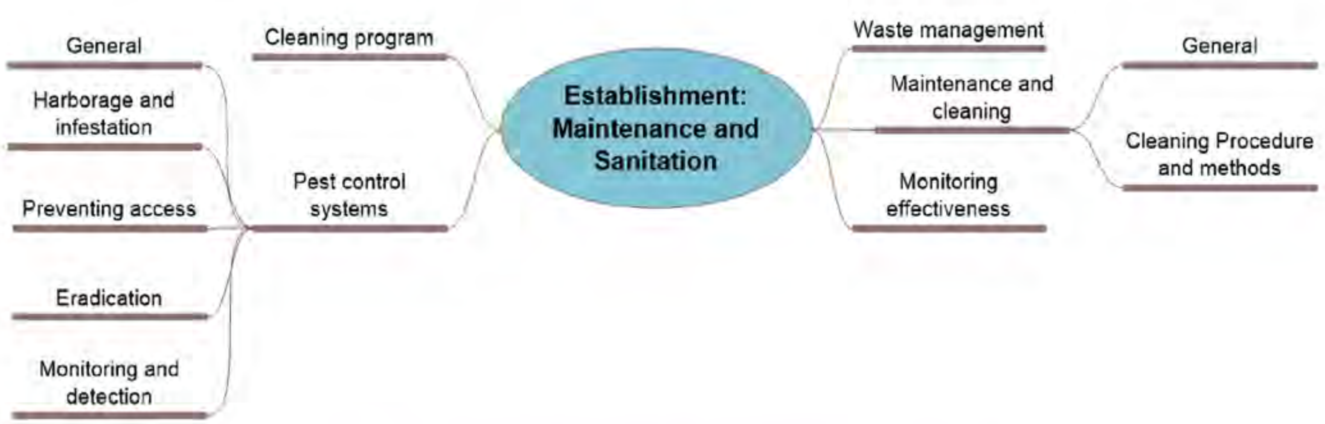


Figure 12. Scope of Establishment : Maintenance and Sanitation

5. Establishment of personal hygiene

A significant factor in food or product spoilage is cross contamination from food handlers or anyone in the food production area. Besides cleanliness, inappropriate activities and health condition of personells are very important to prevent cross contamination. Employees who suffer from illnesses or injured should be absent from the production area. Health conditions that should be considered to be avoided in the area are jaundice, diarrhea, vomiting, fever, cough with fever, sore throat with fever, visibly infected skill lesions, discharge from the ear, eye or nose. They should be moved to another area or rest at home or given treatment based on medical examination. The management can perform a prevention program by developing health criteria during recruitment of employees. Bad personal behavior related with food contamination include smoking, spitting in unappropriate places, chewing or eating in the production area, and unprotected sneezing or coughing. The program should include every person in the food production area including visitors. Management should also implement the same rules and regulation of personal hygiene to visitors, since cross contamination can occur by anyone in the production area.

Figure 13. Scope of Establishment : Personal Hygiene

6. Transportation

Transportation to maintain food hygiene is divided into two areas, inside and outside of the food production area. Transportation activities inside the food production area is transferring the product to the storage area or warehouse while transportation outside the food production area is transferring products from the factory to the markets. These activities have the same objective, yet different type of transportation system. The objective is to keep the product in the same quality when it is received by the first hand in the market. It includes activities to protect the product from physical damage, potential source of contamination, provide suitable environment during transporting to control the growth of pathogens.

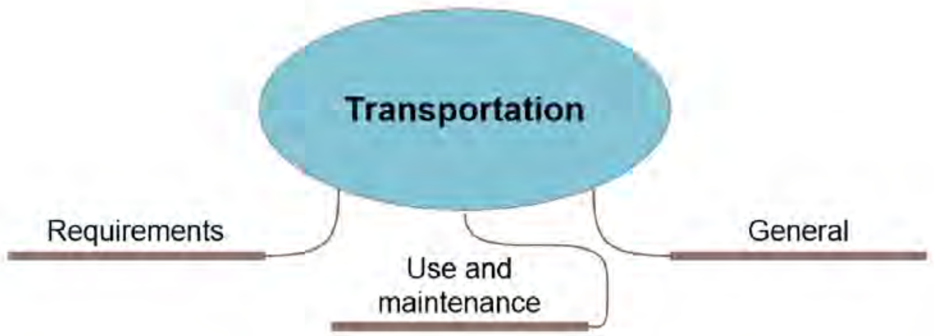


Figure 14. Scope of Transportation

7. Product information and consumer awareness

Products should contain information on production such as lot identification, product handling, including how to store, prepare and use of the product. These information should be put on the lables of food product packaging. The product information is necessary for consumers to be aware about the product. However, not all consumers have the same knowledge in understanding product information. Thus, the awareness on the issue of health, food hygiene and food safety are also still questionable. Increasing awareness of consumers also becomes the responsibility of food industries or companies that should be developed through a health education program so that consumers understand and able to choose food products effectively.

Figure 15. Scope of Product Information and Consumer Awareness

8. Training

Food hygiene training is a basic requirement that should be established. All employees who are involved in food processing or food production should be trained in food hygiene to an appropriate level of operation. Employees should be aware of their role and responsibility in keeping the product/food safe. There are some basic hygiene knowledge and skills which all employees should have. While for advanced-level employees, additioinal training may be required. Training programs for new employees as well as refresher trainings should be condcuted on a routine basis to ensure the maintenance of hygienic practices. Assessment of the effectiveness of the training also needs to be conducted

Figure 16. Scope of Training

5.2. Sanitation Standard Operating Procedures (SSOPs)

Food industry or food service establishment need to ensure a safe-qualified product, therefore it is very important to put in place the cleaning and sanitizing program. SSOPs are the specific, written procedures necessary to ensure sanitary conditions in the industry. The SSOPs are specific to a particular plant, but may be similar to plants in the same or a similar food industry. Local food safety regulations and technical requirements on specific foods are necessary to be referred to the sanitary program. There are **eight keys** area at least needs to be considered in sanitary procedures/program monitoring.

1. **Safety of water** that have contacted with food or food-contact surfaces, or is used in manufacture as ice. The water should be safe, adequate sanitary quality and sufficient for all production activities. To ensure the safety and avoid any potential hazards or contamination, the water-related system should be correctly designed. For example, piping system should be designed well to evade potential back-flow of waste water.
2. **Contamination control from equipment's**
3. **Surface.** All surfaces which have direct contact to the product have to be cleaned and sanitized regularly and effectively, including premises, table, kitchen utensils, gloves, work dress etc. Cleaning and sanitizing should be implemented at pre and post-operational production.
4. **Cross contamination prevention** is necessary since it is frequently lead as source of food poisoning. Prevention of contamination from unsafe food, personnel and practices. Dripping liquid from meat should not be allowed to come into contact with food. Work surfaces, refrigerators and any other equipment on which the meat has dripped should be thoroughly cleaned and sanitised, using a combined detergent/sanitiser. If not available, then hot water >80°C with detergent is a good alternative. Prepared food that will not be eaten immediately should be kept hot (more than 60°C) or cool (below 10°). Separation of raw and cooked food during storage, differentiation of cleaning tools use between safe and unsafe area, ensuring traffic of employees are also necessary to prevent cross contam-

ination during food preparation. Personnel working in food establishments must adopt a code of personal hygiene. They must wash hands before starting to work and throughout the work day, especially after visiting the toilet, touching raw meats or handling garbage. Wounds should be kept covered with waterproof material. Food handlers should avoid sneezing or coughing on food. Food handlers must use protective cloths to prevent contamination. Food handlers and supervisors should receive appropriate training in proper food handling technique and food-protection principles, and should be informed of the danger of poor personal hygiene and sanitary practice. Personnel should be taught proper hand washing procedures. They must also be told to avoid unhygienic behaviour such as smoking, spitting, chewing, sneezing or coughing over unprotected food. Food handlers should not wear jewellery, or carry objects that could drop into the food.

5. **Worker's health control**. Medical examination of a food handler should be carried out only if it is clinically or epidemiologically indicated. However, any person who may be ill, or has visible infected skin lesions (boils, cuts etc.) must not be allowed in any food handling area.
6. **Pest control**. Pest control involves activities such as barrier design and maintenance, prevention of infestation and eradication programs. Regular inspections of production areas, warehouses, and waste disposal sites are necessary.
7. **Hand wash, sanitation and toilet facilities maintenance.** It should be ensured that all areas of the manufacturer are cleaned and sanitized regularly. It may include hand sink, sanitizer and toilet maintenance. Hand sink should be completed with water, soap and hand drier. Furthermore, to reduce the potential of recontamination of clean hands, if possible, the sinks have to have a non-hand-controlled mechanism, such as electronic sensor, knee or thigh control. Every manufacture should provide readily, accessible and adequate toilet facilities.

   Prevention of toxicant chemical. All potential toxicant chemical such as sanitizers, oil, pesticides and other chemicals must be labeled and stored in their specific areas. All toxic chemicals should only be used following the instruction described on the labels.
8. **Product, packaging and surfaces protection from adulteration.** It should be ensured that all areas of the manufacturer are cleaned and sanitized regularly. Cleaning must be followed by sanitizing. Monitoring need to be done regularly in order to eliminate either biology, chemical and physical hazards may occurred including receiving, preparation, processing, storing, packaging and distribution areas.

It is important to have all available sanitation procedures in written to ensure the correct implementation and conducted effectively. Sanitation Standard Operating Procedure is known as written documents containing procedure of cleaning and sanitizing activities. The procedure should be written in clear, step-by-step explanation of the procedures covering what object should be cleaned, where it is located, when or how frequent it should be cleaned, how it is cleaned (procedure of cleaning or sanitizing), who is the responsible person, and describe record used to monitor the procedures. SSOP should be validated before it is implemented and should be reviewed annually. As SSOP should contain brief information as follow:

- Company name
- Date
- Version ID
- Title – Name of the procedure
- Scope/introduction
- Frequency: *frequency of the procedure, for example, should be done once a week, every Thursday, from 6.30-7.30 am*

  Procedure
- Use step by step instruction

  For multiple task, break into section, so that, in gives a clear information
- Specify the use of chemical (type and brand): *chemical concentration, when the procedure begin, how long, temperature needed*

  Record keeping: *identify which form should be used*
- Person responsible: *put the position include signature and date, needed for SSOP content and updates*
- Page numbers

There are two main stages in the operational activities of a food manufacturer, pre-operational and operational stages. These two stages need their own SSOP. Pre-operational SSOPs: these are procedures that describe the daily or routine procedures that are established before processing or production begins. The procedures must include the cleaning of contact surfaces of facilities, equipment and utensils to prevent adulteration or contamination of direct product. This might include explanation of equipment disassembly, reassembly after cleaning, use of acceptable chemical based on the label direction and cleaning technique and application instructions. Operational SSOPS: these are procedures that describe daily or routine procedures that are established during processing or production to prevent direct product contamination or adulteration. The procedure for operational sanitation must perform as sanitary environment for preparing, storing, or handling any meat of poultry product. Established procedures during processing or production might include, where applicable: Equipment and utensils for cleaning/sanitizing procedures, at breaks, between shift and at mid-shift cleanup, employee hygiene procedures, such as hand washing, chealth, hair restraints, and procedures of product handling in raw and in cooked food areas.

It should be remembered in auditing, "when it is not documented, then it is not done". Management support is the main key to the success of the implementation of SSOP by having good training program, monitoring for consistency and documentation.

6 HACCP: PRINCIPLES FOR RISK MANAGEMENT TO ENSURE FOOD SAFETY

6

6.1. Definition, history and benefits of HACCP

Definition and history of HACCP. We know that certain factors affect the survival and growth of microbes. With this knowledge, we can predict and prevent hazards. This approach, called the Hazard Analysis and Critical Control Point (HACCP) approach, was developed by the American National Air and Space Administration (NASA) to prevent hazards at the design stage and during operations of space flight. It was adopted in 1960s by the company responsible for assuring the safety of the food for the astronauts.

With some adaptations, it may be used in different manners and for multiple purposes. For instance, HACCP was originally developed for management of microbiological hazards but experience has shown that with some adaptations it can also be used for the management of chemical, allergens and even physical hazards. It is a concept which permits a systematic approach to identify the hazards and an assessment of the likelihood of their occurrences during manufacture, distribution and use of food product, and defines measures for their control.

Previously, a traditional food safety assurance system relied on two types of measures:

a. Actions undertaken during the procurement of raw material, processing and manufacturing, transport and distribution including design, layout and cleaning of premises, to produce safe food. These actions were usually those prescribed in the Codes of Good Hygienic or Good Manufacturing Practice
b. Actions undertaken to ensure that food was indeed safe. For this purpose, industries tested the "end-product" for contamination, and food control authorities inspected the premises and carried out independent testing.

Traditional food control authorities also inspected the premises for compliance with GHP/GMP and carried out an independent testing of the end-products. The inspection system had many weaknesses. Among others it was based on snap shot inspection, and not on what happened over a longer period of time. End-product testing performed by the industry itself as a means of auto-control or by food inspectors was costly, time consuming and unreliable.

Different with the traditional approach, HACCP is called as modern food assurance system since it use preventive approach. HACCP is a system which identifies, evaluates, and controls hazards which are significant for food safety.

Benefits of HACCP. HACCP is used as a tool for the management of food safety. An ideal HACCP plan can be a means for communicating which hazards are considered in managing food safety and how they are controlled. This is particularly important in supplier-customer relationship.

HACCP approach or philosophy can also be used by different group of professionals for anticipating potential food safety issues, managing them or verifying that they are properly addressed. As such they can be used by product developers, managers involved in production or processing, or inspectors. Similarly, HACCP principles can be applied for the preparation of food in the households or in small businesses e.g. street foods, and based on the outcome of the study, educational messages or codes of practices may be developed.

Limitations of traditional approaches to food safety control:

- Collecting and examining sufficient number of samples
- High cost
- Time consuming
- Identification of problems without understanding the causes
- Limitations of "snap-shot" inspection

The HACCP system has the potential to identify all conceivable, reasonably expected hazards, even where failures have not previously been experienced. It is therefore particularly useful for new operations. The HACCP system is capable of accommodating changes introduced, such as change in supplier, equipment design, product formulation, processing methods and others. With the HACCP system one can expect an improvement in the relationship between food processors and food inspectors & food processors and consumers.

The documentation required under the seventh principle of HACCP, facilitate the inspection by regulatory authorities and/or customers. In this way, it increases the trust among the different parties but also allow to better foresee potential risk with a raw material and a given supplier. This is particularly important if the supplier is distant and a regular visit is not possible.

HACCP can be applied to the whole food chain (from "farm to fork"). At each step the application of HACCP leads to the analysis of hazards at earlier or later stages. In this way it ensures an integrated approach to food safety and promotes the concept of shared responsibility.

It can be integrated in ISO 9000 and complement these standards by providing guidance on how to achieve food safety. ISO 22000 which sets the standards for management of food safety is also requiring the application of HACCP. Thus, application of the HACCP system helps to meet the ISO 22 000 requirements, should such a certification be needed by customers.

HACCP is a method of food safety assurance which was initially developed in food industries for production, processing and manufacturing. However, with some adaptation, it can also be used for the preparation of food in **food service and catering establishments** as well as in street food operations or in homes.

HACCP can also be used in **health education programmes**. There are basically two options:

a) Specific food preparation practices can be studied using the HACCP approach. Measures which would be necessary for ensuring food safety can then be considered in health education programmes.
b) In considering hygienic measures, professional food handlers could be encouraged to take a HACCP-based approach; for instance, they may be trained to understand the importance of heat treatment as a control measure, achieving critical limits in such a process and foreseeing what they could do if failure occurs.

The HACCP system being a systematic approach to analysis of food safety risks during an operation, it can be during investigation of foodborne disease outbreaks to identify the cause of the outbreak. The HACCP system can also be applied on the entire food chain to identify interventions which are required to prevent food safety problems and steps which need to be monitored. In this way, it helps to prioritise interventions which may have the greatest impact on the prevention of the problems.

HACCP is important both for h**ealth and for food trade**. For many years the public health authorities promoted the application of HACCP and many industries have also implemented HACCP on a voluntary basis. However, today its application is required by law in many countries and the Codex Alimentarius Commission also recommends it through its guidelines. With the establishment of the World Trade Organization and entry of force of the Agreement on Sanitary and Phytosanitary measures (SPS) the use of HACCP in products entering international trade has become mandatory.

6.2. Seven (7) principles of HACCP

The seven principles of HACCP according to Codex Alimentarius as follow.

Principle 1
Conduct a hazard analysis

Principle 2
Determine Critical Control Points (CCPs)

Principle 3
Establish critical limit(s)

Principle 4
Establish a system to monitor control of a CCP

Principle 5
Establish the corrective action to be a taken when monitoring indicates that a particular CCP is not under control

Principle 6
Establish procedures for verification to confirm that the HACCP system is working effectively

Principle 7
Establish documentation concerning all procedures and records appropriate to these principles and their application.

The first principle refers to hazard analysis. This is a process consisting of identifying a hazard, and as per definition, collecting and interpreting information on the hazard in question to decide whether it present a significant food safety risk and whether it needs to be addressed in the HACCP plan. By collecting and interpreting information, it is understood that control measures which are in place or which can be implemented need also to be considered. The efficacy of these measures will determine to what extent the hazard in question is likely to be present, grow, survive, or in the context of processing contaminants to be formed, to disease causing levels.

Risk is a function of probability of occurrence of the hazards and severity to the consumer health. The higher probability and severity of the risk may lead to the higher concern to become significant hazard that need to be controlled in HACCP plan.

The second principle refers to determine the Critical Control Points (CCPs) of each identified hazards. Codex defines CCP as a step at which control is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level. The concept of acceptable levels of potentially hazardous agents means that other levels may be unacceptable. Decision tree of Codex will help to identify which step of diagram flow which is CCP for identified hazards.

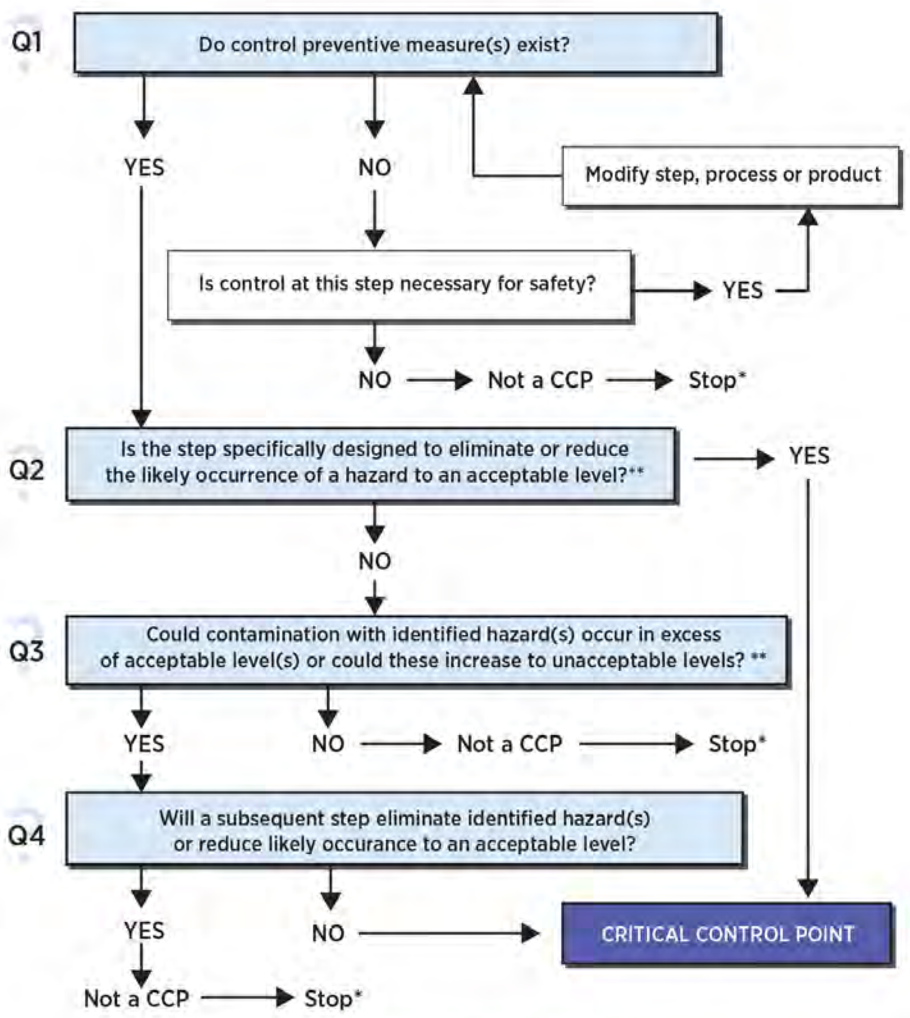


Figure 17. Decision Tree (Codex CAC)

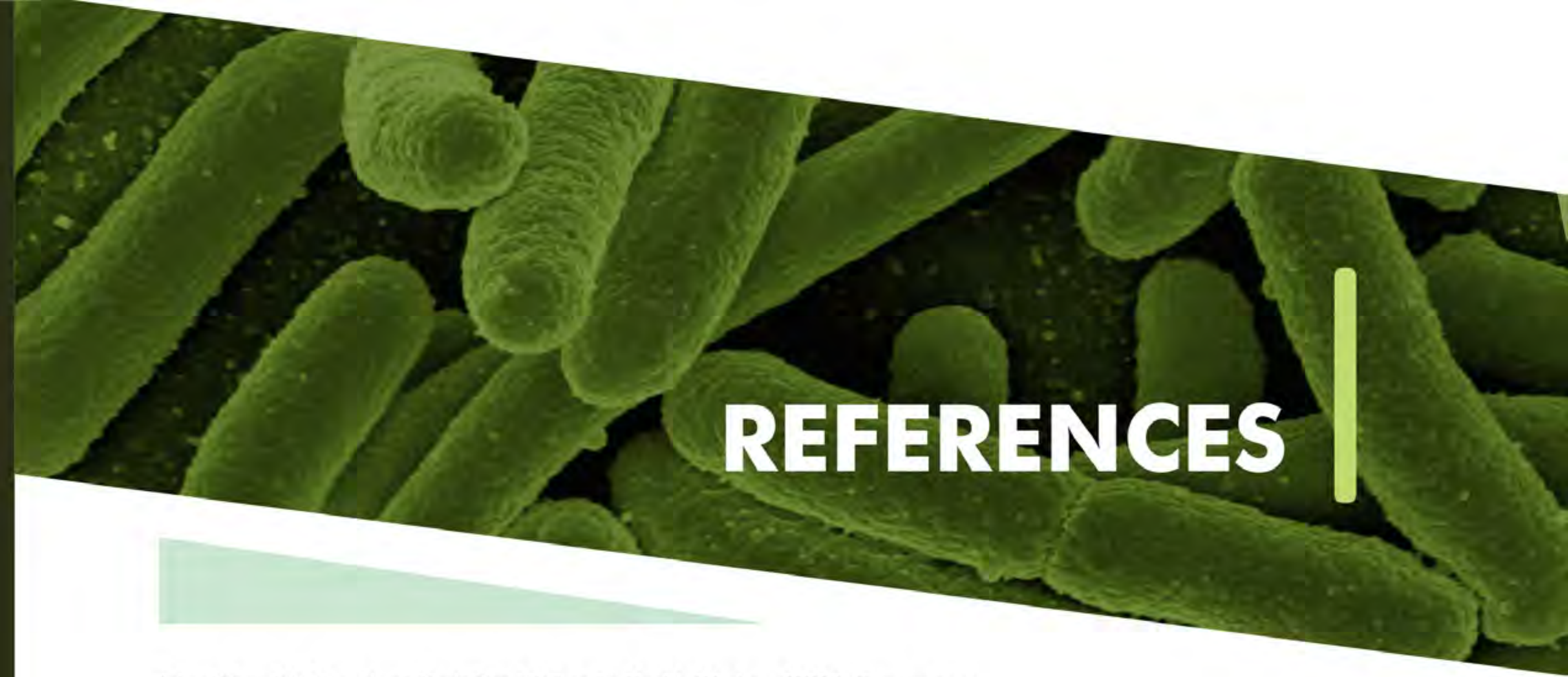
The third principle refers to establish critical limit. The critical limit is the value which separates acceptability from unacceptability for a control parameter. For microbiological hazards, microbiological testing is avoided as a means for controlling a hazard. Instead, their management is based on a process e.g. fermentation, heat treatment, and others. In such a case, the critical limit refers to the limit established for processing parameters such as temperature, time, pH, aW, level of chlorine, and level of cleanliness. There are conditions where the critical limit refers to the level of hazards. This is when the testing is used as a means of control as it is sometimes the case for chemical hazards. For physical hazards such as a metal which can be controlled by a sieve, it is the size of the hazard which is the criterion for acceptability as it determines the size of the mesh.

The fourth principle refers to establish a system to monitor control of a CCP. When monitoring at a CCP shows loss of control, corrective actions are taken to restore control. Here we find the definition of corrective actions as defined by Codex.

The fifth principle refers to establish the corrective action. Corrective action is the application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.

The sixth principle refers to Establish procedures for verification According to the Codex definition, in the context of HACCP, verification is all type of evaluations in addition to monitoring to ensure compliance with the HACCP plan.

The seventh principle refers to Establish documentation concerning all procedures and records appropriate to these principles and their application



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1. Glossary of Terms

Additives and ingredients	Substances added to foods to influence their condition or to bring about specific characteristics or effects (help manufacture, preserve, improve palatability, eye appeal, convenience - e.g. emulsifiers, flavours, thickeners, curing agents, humectants, colours, vitamins, minerals, moulds, yeasts, and bacterial inhibitors).
Aerobic	Refers to any organism that can live in an oxygen atmosphere.
Allergy	A reaction provoked by antigen contact with antibodies. Symptoms include widening of capillaries (reddening of skin or mucous membranes), increase in permeability (local swelling) and secretion (tears, sputum, rhinitis), itching.
Ambient temperature	Surrounding temperature; usually refers to room temperature.
Anaerobic	Refers to any organism that cannot live in an oxygen atmosphere.
Antibiotics	Secondary metabolites of microorganism which, in small quantities, can inhibit or lethally harm another microorganism.
A_w value	The ratio of the water vapour pressure over a food to the saturation pressure of pure distilled water at a given temperature, expressed on a scale of 1.0 to 0.0. Pure water is 1.0 on this scale (WHO). It refers to the amount of water available for growth and multiplication of microorganisms.
Bacteria	A diverse group of single-celled organisms that are neither plants nor animals. Some bacteria are useful; others are harmful.
Botulism	Neuromuscular intoxication caused by Clostridium botulinum toxin. When the vegetative cells grow in a food they produce a potent exotoxin which causes botulism when ingested. It is the most dangerous type of food poisoning and is usually caused by under-processed contaminated canned foods.
Carrier	A person who excretes the organism without showing clinical signs of the disease
Critical Control Point (CCP)	A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level. (Codex)
Critical limit	A criterion that separates acceptability from unacceptability. (Codex)
Cholera	Acute, infectious human disease, usually transmitted by faecal-polluted water, characterised by severe diarrhoea and vomiting, often leading to dehydration.
Contaminant	Any biological or chemical agent, foreign matter or other substances not intentionally added to food that may compromise food safety and suitability. (Codex)
Contamination	The introduction or occurrence of a contaminant in food or food environment. (Codex)
Cross Contamination	A contamination occurring during the production, processing or preparation of food, either through direct contact of uncontaminated materials with contaminated materials or through transmission by a vehicle.
Danger zone	The temperature range most conducive to the multiplication of bacteria (10ºC to 60ºC).
Death phase	The stage during which the viable number of cells in the microbial population declines.
Decontamination	Sanitation, disinfection. Drastic reduction of the microbial population.

Deep freezing	A method to extend the shelf life or keeping quality of a food product by storing it at temperatures below -18oC until it is delivered to the consumer.
Dehydration	Loss of water.
Diarrhoea	Refers to passing a fluid stools with a high frequency. This is the most typical symptom associated with foodborne infection.
Disinfection	The reduction, by means of chemical agents and/or physical methods, of the number of microorganisms in the environment, to a level that does not compromise food safety or suitability. (Codex)
D-value	The time required at a given temperature (e.g. 70oC = D70) to reduce the number of viable cells or spores/endospores of a specific organism by 90% (or 10-fold). The time is quoted in minutes or second; the temperature is indicated by a subscript.
Dysentery	A group of intestinal diseases characterised by abdominal pain and diarrhoea with blood and mucus in the stools.
Endemic	A disease that prevails or recurs frequently in a country or an area, or among (a) particular group(s) of people.
Enteric fever	A term used for typhoid fever or paratyphoid fever types A, B, and C. In some countries these diseases are referred to as typhus and paratyphus.
Epidemic	An outbreak of an infectious disease that affects many people at one time in the same area.
Extrinsic factors	Factors external to a food that may be applied (e.g. by the processor) for extending the shelf life or keeping quality of a food (e.g. temperature, preservatives, storage).
Fermentation	A desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes.
Food handler	Any person who handles packaged or unpackaged food, food equipment and utensils or surfaces in contact with food and is therefore expected to comply with food hygiene requirements. (Codex)
Food hygiene	All conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain. (Codex)
Foodborne disease	A disease, usually either infectious or toxic in nature, caused by agents that enter the body through the ingestion of food. The term "food" includes drinking-water. Sometimes this is incorrectly referred to as food poisoning.
Food poisoning	This is a term that is often used to refer to foodborne illness/disease but WHO does not recommend it.
Food safety	Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. (Codex)
Food spoilage	Food becomes unfit to eat as a result of: growth and activities of microorganisms, insect infestation, action of enzymes, chemical reactions, and physical changes (e.g. freezing, burning, drying, pressure, and humidity).
Food toxin	Compounds naturally present in food that are toxic or carcinogenic or have pharmacological effects. This includes natural carcinogens and nutritional inhibitors.
Food spoilage	Food becomes unfit to eat as a result of: growth and activities of microorganisms, insect infestation, action of enzymes, chemical reactions, and physical changes (e.g. freezing, burning, drying, pressure, and humidity).
Fungus	See Mould.
F value	The number of minutes required to destroy a given number of organisms at a given temperature.
F_0 value	Fo is the time (in minutes) required at 121°C (250°F) to destroy a specified number of spores of *Clostridium botulinum*. It is internationally accepted that a Fo of 3 minutes is a satisfactory process for a low acid canned food; such a process is estimated to kill at least 1012 spores of *Clostridium botulinum*.
Gastro-enteritis	Also known as gut infection. Inflammatory change of the lining of stomach and intestine usually caused by microorganisms ingested with the food or water.
Gut microbes	Microorganisms that live in the gastrointestinal tract of man or animals.
HACCP	"Hazard Analysis and Critical Control Point". A system that identifies, evaluates, and controls hazards that are significant for food safety. (Codex)
Hazard	A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect. (Codex)
Heat sterilisation	Commonly practised method for the destruction (killing) of all viable microorganisms.
Heavy metals	Metals with a specific gravity of >5; Pb, Fe, Cu, Zn, Ni, Cr, Wo, Mo, Cd, Co, U, V, Ag, Au, and Pt, as well as semi-metals As, Sb, and Te. They are found in extremely minute concentrations in all foods and as such do not exert any inhibitory action against microorganisms. Fe, Cu, Zn, and Mo are required as trace elements for the growth or multiplication of microorganisms.
High-risk food	These include foods that have been linked epidemiologically to foodborne disease or that, due to their nature, preparation or storage, present a greater risk of foodborne disease than other foods.

High temperature processing	Process for continuous pasteurisation of milk at 85-90o C for 2 - 4 seconds or equivalent treatment.
Immunity	Part of the defence system of man and animal against infections.
Incubation period	The time interval between exposure to a pathogen or toxin and the appearance of the first clinical symptoms (e.g. 7-21 days for enteric fever). It differs considerably between foodborne infections and intoxication.
Indicator organism	A microorganism used to check the effectiveness of GHP.
Infection	Entry and colonisation of an infectious microorganism in a living macroorganism (host). Disease does not always develop but the host becomes a "carrier".
Intoxication	Bacteria such as *Clostridium botulinum* or *Staphylococcus aureus* grow and produce toxin in the food. When the food is eaten the person becomes ill. In contrast to an infection, the person becomes ill without eating the live bacteria.
Irradiation	Treatment with ionising radiation to render food safe or increase its shelf-life.
Lag (latent) phase	The time taken for a microorganism to adapt to its environment. The lag phase is followed by a phase of active growth.
Malabsorption	Failure to absorb various nutrients.
Mesophile	Microorganism preferring a moderate temperature for growth (between 15-48 °C, with an optimum of about 37°C). This group includes all bacteria and fungi that are pathogenic to warm-blooded animals.
Metabolism	Biochemical process in all living cells. Uptake of nutrients and assimilation in the cell.
Metabolite	An intermediate or end product of microbial metabolism partially excreted in food, with a desired or undesired effect e.g. organic acids, CO_2 and other gases, ethanol, antibiotics, mycotoxins, flavour and other substances influencing the taste.
Microorganisms (microbes)	Simple living creatures comprising viruses, bacteria, algae, protozoa and fungi (fungi include yeast and moulds).
Monitoring (HACCP)	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control. (Codex)
Mould	Refers to any fungus that normally forms a mat of branched elongated cells. Several moulds are useful in the preparation of food (e.g. cheese and Tempe) but many cause spoilage. Some moulds produce harmful mycotoxins.
Mycotoxins	Toxins produced by fungi during growth. The most widely studied mycotoxins are the aflatoxins produced by the moulds *Aspergillus flavus* and *parasiticus*.
Nutrition	The combination of processes by which a living organism receives and uses the material necessary to maintain its function, to grow, and to renew its components.
Ochratoxins	A group of mycotoxins produced by Aspergilli and Penicillia growing on foodstuffs. Ochratoxin A is the best known.
Packaging	A container or wrapping designed to protect food commodities from mechanical and climatic influences, and to act as a barrier to pests and microorganisms.
Pasteurisation	Heating a food to temperatures in the range 60°C to 100°C. Pasteurisation destroys most toxins and vegetative cells of microorganisms causing food poisoning. Most bacterial spores survive pasteurisation.
Pathogenic	Pertaining to the ability to produce disease.
Pathogens	Any disease-causing microorganism or material (bacteria, yeast, fungi, and viruses) that may affect other living organisms, to the detriment of their health.
Pesticides	All compounds used in plant protection against pests.
pH value	Measure of the "acidity" or "alkalinity" of a water-containing product, given as negative logarithm of the H_2O + ion activity (hydrogen ion exponent).
Preservation	Various methods to extend the shelf life of food (e.g. dehydration, heat sterilisation, freezing, radiation, addition of preservatives) by inhibiting the multiplication and/or growth of microorganisms and by minimising chemical and sensory changes.
Preservatives	Antimicrobial substances that prevent multiplication of microorganisms and sometimes also used for preventing other types of undesirable activities.
Risk	A function of the probability of an adverse health effect and the severity of that effect, consequential to (a) hazard(s) in food.
Serotype	Serovars. A serologically (antigenically) distinct variety within a species or genus.
Spore	"Bacterial spores". Extremely resistant survival forms produced by bacteria (genera *Bacillus*, *Clostridium*) under conditions of nutrient limitation.
Sterilisation	In the context of food processing, a method of preservation by killing all microorganisms associated with a foodstuff usually by applying heat, for example in bottling and canning. (WHO)

Strain	A pure culture or microbial isolate of known origin and physiological characteristics; the cells of such culture are accepted to be genetically similar.
Target value	A value or characteristic of a physical, chemical or biological nature, used to assure that critical limits are not exceeded.
Thermal death point	The temperature (in °C or °K) at which all microorganism are killed within 10 minutes.
Thermal death time	Time (in minutes) at a given temperature (°C or °K) required to destroy all microorganisms.
Toxic	Poisonous.
Vector	Also known as a vehicle. Method of transport for microorganisms to hosts or habitats (e.g. wind, water, insects, rodents, pets, man, utensils).
Vegetative cells	Cells able to divide and reproduce the same (identical) form. Vegetative state is more susceptible to heat, radiation, drying, preservatives, disinfectants, and other noxious elements than the spore forms.
Verification	The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan. (Codex)
Viral gastro-enteritis	Collective term for gastro-enteritis caused by viruses, mostly transmitted to man by water, raw salads, and vegetables. The following are described as pathogens: Rota viruses Group A and others, Norwalk viruses and large "related" types, (27 - 32 nm), Adeno-, Astro- and Caliciviruses.
Viral hepatitis	Also known as infectious jaundice. An acute infection that is caused by the type A hepatitis virus. The virus is transmitted from person to person by the faecal-oral route, such as on contaminated food, water and utensils.
Virus	Internal parasites of the cells of many organisms; they are unable to grow outside of the living cells of their host.
Water activity	See A_w value.
Water requirement	Practically all microorganism multiply well at water activities of 1 - 0.98, where sufficient water with dissolved nutrients is available
Yeast	Single-celled fungi that multiply by budding.
Zoonoses	Communicable diseases that can be transmitted to man by animals.

2. Foodborne Diseases Profiles

Bacillus cereus

DESCRIPTION OF ORGANISM	Large Gram-positive, rod shaped, aerobic, spore former, capable of growth under anaerobic conditions
RESERVOIRS OF INFECTION	Soil, dust, cereals, spices, vegetables and dairy products
TEMPERATURE RANGE	Min. 4°C. Optimum 30 - 35°C Max. 48 - 50°C (mesophiles) Max. 43°C (psychrophiles)
RESERVOIRS OF INFECTION	Soil, dust, cereals, spices, vegetables and dairy products
pH RANGE	4.9 - 9.3
a_w	Min. 0.92
SURVIVAL (freezing/drying)	Spores survive freezing/drying.
IONISING RADIATION	1.6 - 4 kGy.
THERMAL RESISTANCE	D- value of 0.02 - 0.06 min. at 121°C. D- value of 0.3 - 27 min. at 100°C. z=10°C.
INFECTIVE DOSE	Toxin produced at 100 cells/g.
MAIN SYMPTOMS (in humans)	Diarrhoeal syndrome: 12 - 24h. Abdominal pain, diarrhoea and nausea. Vomiting syndrome: 6 - 36h. Nausea, vomiting, sometimes followed by diarrhoea.
MODE OF TRANSMISSION	Growth of bacteria in food with subsequent production of enterotoxin OR ingestion of large numbers of spores followed by their germination and enterotoxin production in the ileum.
INCUBATION PERIOD	Diarrhoeal syndrome: 4 - 16h. Vomiting syndrome: 1 - 14h.
TREATMENT	Self - limiting.
RAW FOOD MATERIALS	Cereals, dry vegetables, potatoes, milk and cream, rice, spices.
PROCESSED FOODS	Roast/fried meat products, soups, dry and liquidised egg yolk, custard rice meals

Campylobacter

DESCRIPTION OF ORGANISM	*Campylobacter jejuni* is a Gram-negative slender, curved, motile rod. It is a microaerophilic organism, requiring 3 - 5% oxygen and 2 - 10% carbon dioxide for optimal growth
RESERVOIRS OF INFECTION	Chickens, turkeys and raw milk are the main sources of campylobacter. Healthy pigs, cattle, dogs, cats and wild birds are also sources. Surface waters can be contaminated, and inadequately chlorinated water supplies have been known to cause widespread outbreaks of campylobacteriosis
TEMPERATURE RANGE	The campylobacters that are pathogenic for man will not grow below 30°C, so they will not multiply on chilled food or on ambient stable foods stored below 30°C. The optimum growth temperature is 42°C and the maximum 47°C
pH RANGE	Campylobacters are acid sensitive, having a pH optimum around 7.0 and a pH range of 5.0 to 9.0
a_w	0.987.
SURVIVAL (freezing/drying)	Campylobacters survive freezing for several months in frozen minced meat and poultry. They are very sensitive to drying.
IONISING RADIATION	08 - 31 kGy.
THERMAL RESISTANCE	Campylobacters are heat sensitive. The D -value at 60°C is approximately 6 seconds.
INFECTIVE DOSE	500 - 1000 cells.
MAIN SYMPTOMS (in humans)	Symptoms vary from mild (with few signs of illness even though campylobacter is present in the stool) to severe (with bloody diarrhoea as the most characteristic symptom). Other symptoms are fever, nausea, abdominal cramps and (seldom) vomiting. The duration of the illness is from 2 days to 2 weeks. Complications are relatively rare, but infections have been associated with reactive arthritis, and haemolytic uremic syndrome. Infections of nearly every organ have been associated with cases involving septicaemia. The estimated case/fatality ratio for all *C. jejuni* is one death per 1,000 cases. Children under 5 years and young adults (15 - 29) are more frequently afflicted than other age groups.
MODE OF TRANSMISSION	Bowel to mouth transmission via contaminated food or water.
INCUBATION PERIOD	2 - 5 days.
TREATMENT	The disease is usually self limiting; antibiotic treatment is not recommended except for severe cases.
RAW FOOD MATERIALS	Chicken, turkey and other poultry; less commonly pork and beef . Raw milk.

Clostridium botulinum

DESCRIPTION OF ORGANISM	Gram-positive, anaerobic spore former. 7 types based on antigenic structure of toxin (A - G); only A, B, E and F are known to cause foodborne botulism in man. The organism can be divided into two physiologically distinct groups: proteolytic (A, B, F) and non proteolytic (B, E, F).
RESERVOIRS OF INFECTION	Proteolytic: Predominantly soil borne; found on raw vegetables; sometimes found in raw meat. Non - proteolytic: Found in both fresh and coastal waters and mud, and hence in fish and shellfish.
TEMPERATURE RANGE Proteolytic Non proteolytic	Min. Max. 12.5°C 48°C 3.5°C 48°C.
pH RANGE	*C. botulinum* does not grow below pH 4.6 in foods; growth has been demonstrated at pH 4.0 after prolonged incubation at ambient temperatures.
a_w	Minimum aw for growth at 30 40°C, pH 7.0 : Proteolytic: 0.93 - 0.95. Non proteolytic: 0.97.
SURVIVAL (freezing/drying)	Spores survive freezing and drying.
IONISING RADIATION	1.2 - 6.8 kGy.
THERMAL RESISTANCE Spores	Proteolytic: D -value of 0.2 min. at 121°C. z=10°C. Non - proteolytic: D -value varies widely, approx. 1 min. at 80°C z=10°C. An F0 of 3 min. at 121°C is estimated to kill at least 1012 spores of this organism and is considered a satisfactory heat process.
Toxins	Treatment at 80°C rapidly denatures toxin, e.g. 1000-fold reduction of types A or B toxin in 1 min.
TOXIC DOSE	Disease occurs only when toxin is preformed in the food; this is thought to be when cell concentrations reach 10^3.
MAIN SYMPTOMS (in humans)	Relaxation of muscles, particularly in eyes (causes blurred vision) and around lungs (causes breathing difficulties).
MODE OF TRANSMISSION	Ingestion of food with preformed toxin
INCUBATION PERIOD	Dose related; varies from a few hours to about 8 days.
TREATMENT	Treatment with antitoxins and respiratory support.
RAW FOOD MATERIALS	Low numbers of spores of *C. botulinum* should be anticipated on all raw materials.
PROCESSSED FOODS	Many low acid foods support growth of *C. botulinum*, e.g. fish, meat, vegetables. Under-processed or recontaminated canned foods have been implicated.

Clostridium perfringens

DESCRIPTION OF ORGANISM	*Clostridium perfringens* is an anaerobic, Gram-positive, sporeforming rod.
RESERVOIRS OF INFECTION	It is widely distributed in the environment and frequently occurs in the intestines of humans and many domestic and feral animals. Spores of the organism persist in soil, sediments, and areas subject to human or animal faecal pollution.
TEMPERATURE RANGE	12° - 50°C (optimum 43° - 47°).
pH RANGE	5.5 - 9 (optimum 7.2).
a_w	0.95.
SURVIVAL (freezing/drying)	Sensitive to freezing, can survive in dehydrated foods.
IONISING RADIATION	1.2 - 3.4 kGy.
THERMAL RESISTANCE	Wide variation depending on the heating medium but 6.-.13 minutes at 100°C destroys vegetative cells and spores.
INFECTIVE DOSE	Greater than 10^6 vegetative cells. Toxin production in the digestive tract is associated with sporulation.
MAIN SYMPTOMS (in humans)	The common form of perfringens poisoning is characterised by intense abdominal cramps and diarrhoea. The illness is usually over within 24 hours but less severe symptoms may persist in some individuals for 1 or 2 weeks. A few deaths have been reported as a result of dehydration and other complications.
MODE OF TRANSMISSION	Eating foods highly contaminated with *C.perfringens*.
INCUBATION PERIOD	8 - 22 hours
TREATMENT	Self - limiting
RAW FOOD MATERIALS	Raw meat, poultry, dish, vegetables.
PROCESSED FOODS	In most instances, the actual of poisoning by *C. perfringens* is temperature abuse of prepared foods. Often, small numbers of the organisms survive cooking and multiply to food poisoning levels during cooling and storage. Meats, meat products, and gravy are the foods most frequently implicated.

Pathogenic Escherichia coli

ORGANISM	*Escherichia coli* is part of the normal gut microflora. Most strains are harmless but some are pathogenic and cause distinct diarrhoeal diseases. There are four categories: Enteropathogenic *E. coli* (EPEC). Enteroinvasive *E. coli* (EIEC). Enterotoxigenic *E. coli* (ETEC). Enterohaemorrhagic *E. coli* (EHEC) (see *E.coli O157;H7*).
DESCRIPTION OF ORGANISM	Gram negative; straight, round ended rods. Occur singly or in pairs. Mostly motile. Anaerobic/aerobic.
RESERVOIRS OF INFECTION	Intestinal tract of man and animals. Infected food handlers with poor personal hygiene or water contaminated by human sewage are likely sources of food contamination.
TEMPERATURE RANGE	Minimum: 10°C. Optimum: 37°C. Maximum: 48°C.
pH RANGE	4.4 - 8.5.
a_w	0.93.
SURVIVAL (freezing / drying)	Survives well in frozen state. Can survive drying.
IONISING RADIATION	0.24 - 0.3 kGy.
THERMAL RESISTANCE	D -value of 0.0008 - 0.0017 min. at 77°C. z=5°C.
INFECTIVE DOSE	Probably very low for EHEC. For other pathogenic strains of *E. coli*, the minimal infective dose for adults is probably 10^6 per gram.
MAIN SYMPTOMS (in humans)	EPEC: Infant diarrhoea - typical of young children. Rarely foodborne. EIEC: Dysentery - like syndrome. ETEC: Travellers' diarrhoea - a cholera like heat labile or stable toxin. EHEC: Bloody-diarrhoea syndrome, HUS in 0.5 % of infected children.
MODE OF TRANSMISSION	Bowel to mouth, via contaminated food or water.
INCUBATION PERIOD	EPEC: 17-72h. EIEC: 8-24h. ETEC: 8-44h. EHEC: 3-9 days.
TREATMENT	The diseases are usually self-limiting. Electrolyte replacement therapy may be necessary.
RAW FOOD MATERIALS	Raw meat and fish, vegetables, raw milk, polluted water.
PROCESSED FOODS	Proper cooking readily destroys E. coli. Improper handling can recontaminate any food.

Escherichia coli 0157:H7

DESCRIPTION OF ORGANISM	Gram negative; straight, round ended rods. Occur singly or in pairs. Mostly motile. Anaerobic/aerobic. It belongs to the EHEC, VTEC or STEC type of *E.coli*.
RESERVOIRS OF INFECTION	Intestinal tract of man and animals.
TEMPERATURE RANGE	8° - 44°C (Optimum 37°C).
pH RANGE	4 - 9
a_w	0.95.
SURVIVAL (freezing/drying)	The organism survives well in ground beef in frozen storage, and is more acid tolerant than many other strains of *E.coli*.
IONISING RADIATION	0.24 -0.3 kGy.
THERMAL RESISTANCE	The organism is heat-sensitive (D-value at 63°C of 0.5 min.) and is destroyed by the recommended heating regime for infectious pathogens of 70°C for 2 min. Pasteurisation of milk (72°C/16.2s) will kill more than 104 E. coli 0157 per ml.
INFECTIVE DOSE	The infective dose is not known but is thought to be low.
MAIN SYMPTOMS (in humans)	Acute bloody diarrhoea that develops into haemolytic uremic syndrome (HUS) in 2-7% of cases. Symptoms of HUS include acute renal failure and haemolytic anaemia. There is some evidence that secondary infections such as appendicitis occasionally develop. Verotoxigenic E. coli is the leading cause of acute renal failure in children, which can be fatal. However, illness caused by the organism can also take the form of mild diarrhoea.
MODE OF TRANSMISSION	Via contaminated food and water; person to person transmission has also been implicated in some outbreaks.
INCUBATION PERIOD	3-9 days.
TREATMENT	The illness is self limiting and antimicrobial therapy is not thought to have any effect on the progression of the illness.
RAW FOOD MATERIALS	Undercooked beef, raw milk, sprouts.
PROCESSED FOODS	Proper cooking readily destroys *E. coli*.

Listeria monocytogenes

DESCRIPTION OF ORGANISM	Gram positive, motile by means of flagella. Anaerobic/aerobic.
RESERVOIRS OF INFECTION	Some studies suggest that 1-10% of humans may be intestinal carriers of *L. monocytogenes*. It has been found in at least 37 mammalian species, both domestic and feral, as well as at least 17 species of birds and possibly some species of fish and shellfish. It can be isolated from soil, silage, and other environmental sources.
TEMPERATURE RANGE	0° - 45°C (optimum 37)
pH RANGE	4.6 - 9.2 (optimum 7).
a_w	0.92.
SURVIVAL (freezing/drying)	*L. monocytogenes* is quite hardy and resists the deleterious effects of freezing and drying.
IONISING RADIATION	0.2 - 1 kGy.
THERMAL RESISTANCE	Normally killed by pasteurisation treatment (71°C for 15 seconds).
INFECTIVE DOSE	Most persons can tolerate 1,000 organisms without ill effect. Higher intakes may cause illness in susceptible persons such as the very young, the very old, diseased persons and persons with a compromised immune system.
MAIN SYMPTOMS (in humans)	The manifestations of listeriosis include septicaemia, meningitis (or meningoencephalitis), encephalitis, and intrauterine or cervical infections in pregnant women, which may result in spontaneous abortion (2nd/3rd trimester) or stillbirth. The onset of the aforementioned disorders is usually preceded by influenza-like symptoms including persistent fever. It was reported that gastrointestinal symptoms such as nausea, vomiting, and diarrhoea may precede more serious forms of listeriosis or may be the only symptoms expressed.
MODE OF TRANSMISSION	Eating contaminated food.
INCUBATION PERIOD	The onset time to serious forms of listeriosis is unknown but may range from a few days to three weeks. The onset time to gastrointestinal symptoms is unknown but is probably greater than 12 hours.
TREATMENT	Antibiotics. When infection occurs during pregnancy, antibiotics given promptly to the pregnant woman can often prevent infection of the foetus or new-born.
RAW FOOD MATERIALS	Raw milk, raw vegetables fermented raw-meat sausages, raw meats, and raw and smoked fish.
PROCESSED FOODS	*L. monocytogenes* has been associated with such foods as cheeses (particularly soft-ripened varieties), paté and meat products. Its ability to grow at temperatures as low as 3°C permits it to multiply in refrigerated foods.

Mycotoxins

DESCRIPTION OF ORGANISM	The primary mycotoxin is aflatoxin produced by Aspergillus flavus. This fungus can grow on the ears of corn and cottonseed and as a saprophyte on peanuts, nuts, spices and other agricultural products. Other mycotoxins can be produced by Fusarium species (several toxins) Penicillium verrucosum and A. ochraceus (nephrotic ochratoxin A in feed and slaughter pigs and chickens).
TEMPERATURE RANGE	10° - 40°C (optimum 33°C).
pH RANGE	2 -11 (5.-.8 optimal).
a_w	0.80 - 0.99.
SURVIVAL (freezing/drying)	Mycotoxins need a warm, damp environment to grow.
IONISING RADIATION	Irradiation will not usually degrade the toxin.
THERMAL RESISTANCE	Many mycotoxins are not very heat sensitive and often are only partly broken down by or sterilisation.
INFECTIVE DOSE	Not known. Concern is with their carcinogenic effects.
MAIN SYMPTOMS (in humans)	Mycotoxins have a range of toxic effects and can cause damage to kidneys, liver, skin as well as carcinogenic and haemorrhagic effects. Only aflatoxin and ergot alkaloids are reported as a cause of illness. Aflatoxin has been reported as a cause of acute hepatitis in many African and Asian countries. Aflatoxins have also been associated with cancer of the liver in Africa and Southeast Asia. Incidences of ergotism have occurred in Ethiopia and India.
MODE OF TRANSMISSION	Mycotoxin induced illness is mainly caused by alimentary exposure to contaminated foodstuffs; other routes may include airborne exposure to mycotoxin containing spores and mycelial fragments.
INCUBATION	Not known.
TREATMENT	Not known.
RAW FOOD MATERIALS	Agricultural products, e.g. cereals, rice, peanuts. Milk and poultry can also be contaminated if feed contains mycotoxins. Reports from Indonesia indicate that more than 80% of local corn-based poultry feeds are contaminated with aflatoxins. Fungal growth and mycotoxin contamination are common because the main harvest months of January and February occur during the rainy season and only sun drying is used to reduce moisture content prior to wholesale packing.

Salmonellae

DESCRIPTION OF ORGANISM	*Salmonella* is a rod-shaped, motile bacterium (nonmotile exceptions *S. gallinarum* and *S. pullorum*), non-spore-forming and Gram-negative. Anaerobic/aerobic.
RESERVOIRS OF INFECTION	Contaminated poultry, eggs and meat provide a source of infection for Salmonella, which are nurtured through intensive farming and improper food handling. In addition, inedible parts of animals are often processed for livestock feeds, resulting in the presence of viable salmonellae in feeds.
TEMPERATURE RANGE	Minimum 5°C - 7°C. Optimum 35°C - 37°C. Maximum 47°C.
pH RANGE	4.5 - 9.0, optimum 6.5 7.5.
a_w	0.92.
SURVIVAL (freezing/drying)	*Salmonella* may survive for extended periods in dried foods, depending on the relative humidity and storage atmosphere. In low moisture foods, the bacterium may remain alive for years. Although freezing reduces levels of the pathogen, *Salmonella* remains viable for a long time in frozen meat and poultry.
IONISING RADIATION	0.1 - 4.8 kGy (depends on strain and food).
THERMAL RESISTANCE	D-value of *S. enteritidis* at 55°C is approximately 8.2 min. and that of *S. typhimurium* 3.3 min. Specific strains of *S. senftenberg* are more heat resistant with a D-value of approximately 31 min. at 57°C or 1 - 2 seconds at 71.7°C. The minimum thermal process to achieve a 6 log reduction in numbers is 70°C / 2 min., moist heat.
INFECTIVE DOSE	Depends on serotype, the characteristics of the consumer and the food. For healthy adults, a dose of 10^3 bacteria per g in the food is usually required, but for susceptible individuals, the dose may be less than 10 cells. Fatty foods such as hamburgers, cheese and chocolate protect the organisms from gastric juices, thus lowering the infective dose.
MAIN SYMPTOMS (in humans)	Diarrhoea, abdominal cramps, vomiting and fever. Long term non gastrointestinal complications such as arthritis may arise. Susceptible victims may die (0.1 - 1 %).
MODE OF TRANSMISSION	Via contaminated food, particularly poultry, meat, milk, eggs and egg products, but also raw vegetables. Person-to-person transmission can occur in areas where hygiene is poor.
INCUBATION PERIOD	Usually 12 - 36 h but can be as long as 6 - 7 days. Fever may last up to 7 days.
TREATMENT	Self-limiting. Rehydration may be necessary.
RAW FOOD MATERIALS	Poultry and eggs, raw milk, vegetables, shellfish, spices and herbs. Raw meat.
PROCESSED FOODS	Sauces and salad dressing, cake mixes, cream-filled desserts and toppings, dried gelatine, peanut butter, cocoa, chocolate.

Shigella

DESCRIPTION OF ORGANISM	Shigellae are Gram-negative, nonmotile, nonsporeforming rod-shaped bacteria. Anaerobic/aerobic.
RESERVOIRS OF INFECTION	Humans and the higher primates.
TEMPERATURE RANGE	6° - 47°C.
pH RANGE	4.8 - 9.4.
a_w	0.96.
SURVIVAL (freezing/drying)	Can survive in foods at -20°C, and can survive drying for several weeks.
IONISING RADIATION	0.2 - 0.4 kGy
THERMAL RESISTANCE	D-value of 10 seconds at 80°C.
INFECTIVE DOSE	As few as 10 cells depending on age and condition of host.
MAIN SYMPTOMS (in humans)	Infections are associated with mucosal ulceration, rectal bleeding and dehydration; fatality may be as high as 10-15% with some strains. Reiter's disease, reactive arthritis, and haemolytic uremic syndrome are possible sequelae that have been reported in the aftermath of shigellosis.
MODE OF TRANSMISSION	Person-to-person via the faecal-oral route, contaminated water and lettuce.
INCUBATION PERIOD	12 to 50 hours.
TREATMENT	Shigellosis can usually be treated with antibiotics. Unfortunately, some *Shigella* bacteria have become resistant to antibiotics and using antibiotics can make the germs more resistant in the future. Persons with mild infections will usually recover quickly without antibiotic treatment
RAW FOOD MATERIALS	Salads (potato, tuna, shrimp, macaroni, and chicken), raw vegetables, milk and dairy products, and poultry.
PROCESSED FOODS	Many processed foods that have not been (re)heated properly have been implicated.

Staphylococcus aureus

DESCRIPTION OF ORGANISM	Occur as grape-like clusters of cocci. Non-motile, non - spore forming. May produce very heat resistance enterotoxins. (A, B, C, D, E) above 10°C. Anaerobic/aerobic.
RESERVOIRS OF INFECTION	Man: nose, hand, skin infections. Poultry: skin. Raw meat.
TEMPERATURE RANGE	Minimum: 6.5°C. Optimum: 37 - 40°C. Maximum: 48°C.
pH RANGE	4.0 - 9.8.
a_w	0.83.
SALT TOLERANCE	Survives at up to 15% NaCl.
SURVIVAL (freezing / drying)	Survives very well, especially in the dried state.
IONISING RADIATION	1 - 10 kGy.
THERMAL RESISTANCE	D-value at 77°C of 0.001 - 0.0105 min. z = 8 - 12°C.
INFECTIVE DOSE	Minimum levels for toxin production is 10^6 cells per g food.
MAIN SYMPTOMS (in humans)	The onset of symptoms is usually rapid and in many cases acute, depending on individual susceptibility, the amount of contaminated food eaten, the amount of toxin in the food ingested, and the general health of the victim. Common symptoms are nausea, vomiting, abdominal cramping, and prostration. In more severe cases, headache, muscle cramping, and transient changes in blood pressure and pulse rate may occur. Recovery generally takes two days. However, it is not unusual for complete recovery to longer in severe cases.
MODE OF TRANSMISSION	Growth of organisms and subsequent toxin production in food.
INCUBATION PERIOD	1 - 6 h.
TREATMENT	Self-limiting.
RAW FOOD MATERIALS	Raw poultry , sometimes dairy products and meat
PROCESSED FOODS	Cream -filled bakery products; sandwich fillings, and milk and dairy products and extensively "handled" food.

Vibrio cholerae

DESCRIPTION OF ORGANISM	These are Gram-negative, non-sporing, non-acid fast rods that may be straight or curved. Anaerobic/aerobic.
RESERVOIRS OF INFECTION	The V.cholera is often found as part of the normal flora of brackish waters and estuaries. The numbers of organisms here are normally very low, but build up when sewage from infected persons pollutes the water. Fish and shellfish caught in polluted waters have a high probability of causing cholera if they are eaten either raw or without adequate cooking. The epidemic in Peru appears to have been spread by the staple diet or ceviche (raw fish "marinated" in lemon juice).
TEMPERATURE RANGE	15° - 42°C.
pH RANGE	6 - 10
a_w	0.97.
SURVIVAL (freezing/drying)	The vibrio is sensitive to drying, so dried foods are unlikely to cause disease. Freezing below 20°C will reduce, but may not completely eliminate cholera organisms from food.
IONISING RADIATION	10 kGy .
THERMAL RESISTANCE	The *V.cholera* is sensitive to heat so the heating regime of 70°C for 2 minutes (which is recommended to destroy all other infectious pathogens) will also destroy the *V.cholera*.
INFECTIVE DOSE	It is believed that millions of vibrios (e.g. 10^6 - 10^8) are needed to infect a person who has normal gastric acidity, but only about 1000 cells if gastric acidity is low.
MAIN SYMPTOMS (in humans)	Profuse, watery diarrhoea with vomiting and muscle cramps lasting for a few days; dehydration and salt imbalance may follow. Onset is usually rapid and patients may dehydrate within hours if not treated. Mild diarrhoea is also common and symptoms resemble those of traveller's diarrhoea.
MODE OF TRANSMISSION	Via contaminated food or water; person to person spread occurs only where personal hygiene and sanitation are poor.
INCUBATION PERIOD	1-5 days.
TREATMENT	With proper oral and/or intravenous rehydration therapy, treatment is simple and effective; case fatality rates are <1%. Antibiotics are not usually needed.
RAW FOOD MATERIALS	Raw fish and shellfish harvested from polluted waters. Vegetables and fruit irrigated or washed with polluted water or iced with polluted ice.
PROCESSED FOODS	The only manufactured product known to have been the source of infection was mineral water unhygienically bottled in Portugal in 1974. However fresh foods prepared by caterers and served in restaurants or on aircraft have caused serious incidents.

Yersinia enterocolitica

DESCRIPTION OF ORGANISM	Small rod-shaped, Gram-negative bacterium. Anaerobic/aerobic
RESERVOIRS OF INFECTION	Strains of *Y. enterocolitica* can be found in meats (pork, beef, lamb, etc.), oysters, fish, and raw milk. Pigs seem to be the main reservoir.
TEMPERATURE RANGE	0°- 44°C.
pH RANGE	4.6 - 9.0.
a_w	0.945.
SURVIVAL (freezing/drying)	Resistant to freezing (can survive several months in frozen meat).
IONISING RADIATION	38 kGy.
THERMAL RESISTANCE	D-value 1 minute at 60°C.
INFECTIVE DOSE	Unknown.
MAIN SYMPTOMS (in humans)	Yersiniosis is frequently characterised by symptoms such as gastro-enteritis with diarrhoea and/or vomiting; however, fever and abdominal pain are the hallmark symptoms. Yersinia infections mimic appendicitis and mesenteric lymphadenitis, but the bacteria may also cause infections of other sites such as wounds, joints and the urinary tract.
MODE OF TRANSMISSION	Human-to-human, animal-to-human, or via environmental sources such as food and water.
INCUBATION PERIOD	24 - 48 hours.
TREATMENT	Infection usually passes quickly without antibiotic treatment.
RAW FOOD MATERIALS	Raw pork.
PROCESSED FOODS	Dairy products, sausages.