Chapter 1

# Food Safety – Problems and Solutions

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Additional information is available at the end of the chapter

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**Abstract**

When certain disease-causing bacteria, viruses or parasite contaminate food, they can cause food-related diseases. Another word for such a bacterium, virus, or parasite is "pathogen". Since food-related diseases can be serious, or even fatal, it is important to know and practice safe food-handling behaviors to help reduce the risk of getting sick from contaminated food. According to the Codex Alimentarius Commission (CAC), "food safety is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use". Foodborne diseases are widespread throughout the world. The process by which a foodborne disease spreads begins with the features of the disease, contaminating the food, which in turn threatens both individual and public health by means of the foods. Healthy, or what can be termed as safe food, is food that has not lost its nutritional value, that is clean, in physical, chemical and microbiological terms and that is not stale. The factors causing the contamination of the food may threaten the safe consumption of it and thereby make the foods harmful to human health. For this reason, it is necessary to utilize various resources to prevent the food from being contaminated in all stages of the food chain, from harvest to consumption. The aim of this chapter is to determine the factors affecting food safety and proffer effective intervention strategies against food-related diseases.

**Keywords:** Food safety, food hygiene, food handlers hygiene, kitchen and equipment hygiene, nutrition

## 1. Introduction

The diseases caused by food, or the foodborne diseases, are described as the illnesses with which people are infected by the foods they eat [1]. These diseases are a widespread public health issue and are expensive to treat [2]. Foodborne diseases result from the consumption of contaminated foods and products. Contamination of the food at any stage, from production to consumption, produces bacteria, viruses, parasites, chemical agents and toxins, which eventually cause the foodborne diseases [1].

These diseases are seen as a pervasive, permanent problem that can lead to morbidity and, occasionally, to mortality. Foodborne diseases are increasing worldwide, particularly in the developing countries, due to neglect of personal hygiene and food hygiene [3].

Foodborne illnesses pose a threat to international public health safety and economic development. With the increasing amount of trade, travel and immigration, the rate at which dangerous contaminants and pathogens pass through the borders has also risen. Every year, approximately 2.2 million people, a majority of whom are children living in developing countries, die as a result of food and water contamination [1]. Typhoid fever occurs in 16.6 million people and causes 600,000 deaths every year around the world. In the United States, contaminated foods are seen as being responsible for nearly 76 million infections, 325,000 hospital cases and 5000 deaths every year [4]. According to 2011 data from the Centers for Disease Control and Prevention (CDC), it was estimated that in the United States, one out of every six persons was infected with foodborne illness (48 million people) and that foodborne illnesses resulted in 128,000 hospital cases and 3000 deaths [5].

In 2013, FoodNet, a CDC-established program that tracks foodborne illnesses in the United States, found that foodborne illnesses were responsible for 19,056 infections, 4,200 hospital cases and 80 deaths. The incidence of bacteria responsible for causing diseases in every 100.000 people was determined to be 15.19 for *Salmonella*, 13.82 for *Campylobacter*, 4.82 for *Shigella*, 2.48 for *Cryptosporidium,* 1.15 for *STEC non-O157*, 0.51 for *Vibrio*, 0.36 for *Yersinia*, 0.26 for *Listeria* and 0.03 for *Cyclospora*. Incidences of *Cyclospora*, *Listeria* and *Vibrio* were found to be the highest among the elderly, aged 65 years and older, whereas for all of the other pathogens, the highest incident rates were found among children younger than 5 years of age [6].

The diseases caused by *Salmonella* and *Campylobacter*, the main agents responsible for foodborne infections, are dramatically increasing in some countries, including Denmark, Finland, Iceland, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom. In 1999 and 2000, the number of reported foodborne disease cases was 84,340 and 77,515, respectively in Turkey. While *Salmonella* is the most frequently encountered disease agent, the actual figures on foodborne infections and toxins are not reflected, as it is not mandatory to report these diseases [7].

The world's growing population and the consumers' desire to be provided with a wider range of foods have resulted in a longer and more complex food chain. Today, foods reach consumers after being collected from fields, farms and factories and then pass onto many countries, traveling distances of thousands of kilometers. With this global food distribution, an infection that occurs at any point within the food chain has the potential of affecting any given population in the world. It is therefore essential, given the number of interactions taking place between the actors involved in the food chain and the long distances between them, that multisectorial and international collaboration take place. As no country can provide food safety on its own, safety measures need to be enhanced in many countries [8].

While experts on food safety and health have determined that millions of foodborne disease cases are reported every year, the actual numbers are clouded by uncertainty, as most cases go unreported. Furthermore, foodborne diseases are difficult to diagnose, since they have

various symptoms, including fatigue, chills, mild fever, vertigo, upset stomach, dehydration caused by diarrhea, severe cramps and, in some cases, even death. In many of the reported cases, foods prepared outside of the home are the primary cause of foodborne diseases, though it is not uncommon for home-made foods to also cause diseases [9]. Studies conducted on the distribution of foodborne diseases across the world have demonstrated that a majority of these diseases occur during the processing of the food in the preparation stage at home or at food production sites [10]. In fact, most foodborne diseases can be prevented if the regulations governing food safety were complied with, from production stages to consumption [11].

Improper heating of the food, such as undercooking, re-heating and waiting in the heat, or improper cooling of the food account for 44% of the foodborne illnesses. Inadequate preparation and improper cooking practices, such as those involving cross-contamination, insufficient processing, poor hygiene and the re-use of leftovers, are responsible for causing 14% of these diseases [7].

As indicated by these figures, foodborne diseases are widespread throughout the world. The process by which a foodborne disease spreads begins with the features of the disease contaminating the food, which in turn threaten both individual and public health by means of the foods. Healthy, or what can be termed as safe, food is food that has not lost its nutritional value, that is clean, in physical, chemical and microbiological terms and that is not stale. The factors causing the contamination of the food may threaten the safe consumption of it and thereby make the foods harmful to human health. For this reason, it is necessary to utilize various resources to prevent the food from being contaminated at all stages of the food chain, from harvest to consumption [12].

This study conducts an analysis of the factors responsible for jeopardizing food safety and food safety policies throughout the world.

## 2. The factors that affect food safety

Foods are the basic building blocks of living things, yet they may pose a threat and become harmful to human health in some situations [13]. Many people throughout the world become ill because of the food they eat. These diseases associated with food consumption are referred to as foodborne diseases, and they may result from dangerous microorganisms [14]. Foods can become harmful to human health or even fatal when combined with bacteria, mold, viruses, parasites and chemical toxins [13]. Therefore, it is absolutely necessary that consumers be provided with a safe food supply. The factors involved in the potential threat caused by foods are inappropriate agricultural practices, poor hygiene at any stage of the food chain, lack of preventive controls during processing and preparation of the food, incorrect use of the chemical materials, contaminated raw materials, food and water and inappropriate storage [15].

These issues were classified into three categories: **food hygiene**, **personal hygiene of food handlers** and **kitchen sanita**tion.

### 2.1. Food hygiene

Many factors serve to undermine food hygiene. The hygienic quality of the foods is negatively influenced by purchasing low-quality or stale foods, storing food in inappropriate conditions, cooking large amounts of food, more than is necessary, and letting it sit in inappropriate environments, storing raw and cooked foods together and preparing, cooking and storing food using incorrect methods [13]. If foods are contaminated at any stage, from production to consumption, the hygiene of the food is compromised, depending on the temperature, humidity and pH values of the environment it is stored in, and the food then becomes potentially harmful to human health. An infection or intoxication caused by the consumption of a contaminated food or drink is called food poisoning [16]. The causes of food poisoning are classified as microorganisms, parasites, chemicals, naturally created food toxins, naturally created fish toxins, metabolic disorders, allergic reactions and radioactive substances [17].

*Salmonella, Campylobacter* and *Enterohemorrhagic Escherichia coli* (EHEC) are foodborne pathogens that affect millions of people every year. Symptoms of food poisoning caused by these pathogens include fever, headache, upset stomach, vomiting, abdominal pain and diarrhea. Although food poisoning is mostly caused by bacteria, some parasites and viruses can also be factors. Parasites such as *Trichinella spiralis* and *Toxoplasma gondii* can remain alive by using the nutritional elements in the carrier. Viruses such as *Hepatitis A* can behave like parasites and infect people as well as the entire food chain [9,18].

*Staphylococcus aureus, Clostridium perfringens, Salmonella, Streptococcus, Shigella, Clostridium botulinum, E. coli 0157:H7, Campylobacter* and *Bacillus cereus* are the microorganisms that most frequently cause food poisoning [9,13,18,19].

*S. aureus* is a gram-positive coccal bacterium about 0.5–1.0 μm in diameter. The optimum growth temperature is 37° C. The normal ecological habitat of *S. aureus* is human body [16]. *S. aureus* can be cultured from multiple sites of the skin and mucosal surfaces of carriers; the primary reservoir of staphylococci is thought to be the nostrils of the nose. Spread of *S aureus* generally is through human-to-human contact. Carriage of *S. aureus* in the nose appears to play a key role in the epidemiology and pathogenesis of infection. In the general population, a mean carriage rate of 37.2% was found [20]. *S. aureus* is conveyed to the food by the person handling it. Persons with skin, nose or throat infections or inflammatory wounds pass this microorganism onto the food. The foods posing a particular risk for containing *Staphylococcus* include cooked meat, potato salad, desserts with milk, such as custard, and chicken, fish and other meat salads [9,13,21]. It causes food poisoning by releasing enterotoxins into food. After 3–6 hours of consuming contaminated food, symptoms begin. The most marked and severe symptoms are nausea and vomiting. The others are stomachache and diarrhea [16]. This bacterium cannot be eliminated by cooking. Therefore, it is necessary to keep foods refrigerated; the use of aprons and gloves by staff reduces skin-to-skin contact and, therefore, the staff should further follow the rules of hygiene and minimize physical contact with food [9,13,21]. For staphylococcal food poisoning, phage typing can be performed to determine whether the staphylococci recovered from the food were the source of infection. Depending on the type of infection present an appropriate specimen is obtained accordingly and sent to the laboratory for definitive identification using biochemical or enzyme-based tests. Furthermore, for

differentiation on the species level, catalase, coagulase, DNAse, lipase and phosphatase tests are all done [19].

*C. perfringens* is a gram-positive, rod-shaped anaerobic, spore-forming pathogenic bacterium [19]. *C. perfringens* is very common in nature. Especially, it is found in the digestive system of humans as well as of animals and in soil [13]. This bacterium is the third most common cause of foodborne illnesses in the United Kingdom and United States. According to some estimates, this type of bacteria causes nearly a million illnesses each year. Poisoning occurs after contamination of foods. Cooking kills the growing *C. perfringens* cells that cause food poisoning, but not necessarily the spores that can grow into new cells. If cooked food is not promptly served or refrigerated, the spores can grow and produce new cells [22]. Because the spores of some strains are resistant to temperatures as high as 100°C for more than l h, their presence in foods may be unavoidable. Furthermore, the oxygen level may be sufficiently reduced during cooking to permit growth of the clostridia. Spores that survive cooking may germinate and grow rapidly in foods that are inadequately refrigerated after cooking [23]. It easily reproduces in meat that has been sitting at room temperature for a long time after being cooked, in undercooked and repeatedly re-heated meat and in meat served cold [13,19]. *C. perfringens* cells lose their viability when foods are frozen or held under prolonged refrigeration unless special precautions are taken. Such losses may make it difficult to establish *C. perfringens* as the specific cause of a food poisoning outbreak. It is recommended that samples that cannot be examined immediately be treated with buffered glycerin salt solution and stored or shipped frozen to the laboratory [23]. It can be detected in contaminated food [if not heated properly) and feces. Incubation time is between 6 and 24 hours after consuming of contaminated food [24]. Usual symptoms typically include abdominal cramping, diarrhea; vomiting and fever. Very rare, fatal cases of clostridial necrotizing enteritis (also known as pigbel) have been known to involve "Type C" strains of the organism, which produce a potently ulcerative β-toxin. Many cases of *C. perfringens* food poisoning likely remain subclinical, as antibodies to the toxin are common among the population. This has led to the conclusion that most of the population has experienced food poisoning due to *C. perfringens*. Despite its potential dangers, *C. perfringens* is used as the leavening agent in salt rising bread. The baking process is thought to reduce the bacterial contamination, precluding negative effects [25]. This microorganism can be prevented from harming the food by cooling the cooked food rapidly, saving leftover food in shallow containers and storing food in appropriate conditions [13,19].

*Salmonella* is a rod shaped bacteria and can live in a variety of habitats. Some strains of *Salmonella* live in water, soil, food plants and feces of contaminated humans. Generally the bacterium is able to access those places through cross-contamination of already-infected organisms or feces. When present in water, *Salmonella* can live for several weeks; in soil the bacteria can live up to several years, while in feces the bacteria may only survive a few days. The bacteria can survive in salt water and cooler environments, but a too hot of an environment may kill the bacteria [19,26]. Salmonellosis in humans is generally contracted through the consumption of contaminated food of animal origin (mainly eggs, meat, poultry and milk), although other foods, including green vegetables contaminated by manure, have been implicated in its transmission. Person-to-person transmission through the fecal–oral route can

also occur. Human cases also occur where individuals have contact with infected animals, including pets [27]. Usually, symptoms start 12–72 hours after ingestion of bacteria. It is usually characterized by acute onset of diarrhea, fever, abdominal cramps, nausea and vomiting. In most cases, the illness lasts for 4–7 days, and most people recover without treatment. But, *Salmonella* can cause more serious illness in older adults, infants and persons with chronic diseases [26]. *Salmonella* food poisoning has long been, and continues to be, an important global public health problem. In much of Europe and North America, *Salmonella* is mostly found in raw or undercooked chicken, meat, eggs and fish and in unpasteurized milk. It is very easy to control and can be killed by cooking foods at sufficiently high temperatures. To prevent *Salmonella* contamination, the food should be stored at appropriate temperatures, sanitation and hygiene rules should be followed and rodents and flies should be removed from the work environment [9,13,27].

*Streptococcus* is a gram-positive and nonmotile bacterium and the name refers to the bacterium's characteristics of grouping in chains that resemble a string of beads. The natural habitat of the bacteria are pharynx, rectum and skin [19]. Certain *Streptococcus* species are responsible for many cases of pink eye, meningitis, bacterial pneumonia, endocarditis, erysipelas and necrotizing fasciitis [18]. *Streptococcus* is found inside the human mouth, on hands and in nose secretions and can be conveyed to foods through contact with these secretions. For this reason, infected persons should not prepare food, and the food should be kept in appropriate conditions after being cooled rapidly [19,21].

*Shigella* is a nonmotile, gram-negative, facultative anaerobic, non–spore-forming, rod shaped bacterium. It is one of the leading bacterial causes of diarrhea worldwide [28]. *The primary host and natural reservoir known at this point for Shigella* is the human gastrointestinal tract. *Shigella* can survive in fecal-contaminated material but has a low survival rate without the optimal acidic environment in the intestinal tract [29,30]. They can easily multiply between 10 and 48 °C [16]. The optimum growth temperature for this bacterium is 37 °C [30]. There are two different mechanisms for pathogenicity. Firstly, bacterial number increases very fast in intestine and then settles into mucosal entry and colon. Because they may cause leakage of blood into the lumen, bloody diarrhea occurs. Secondly, the production of endogenous toxin, which is known as *Shiga toxin*, results in diarrhea [16]. *Shigella* infection typically occurs by ingestion (fecal–oral contamination); depending on age and condition of the host, fewer than 100 bacterial cells can be enough to cause an infection. Food prepared by the contaminated person may easily become contaminated with *Shigella* bacteria [30]. Symptoms of shigellosis include mild to severe diarrhea, bloody diarrhea, fever, dehydration, nausea, vomiting and stomach cramps. They usually appear between 1 and 7 days after contracting the bacteria [31]. The diagnosis of shigellosis is made by isolating the organism from diarrheal fecal sample cultures. It can infect the food in any environment where hygiene rules are not followed. The most important protective factor against *Shigella* is to follow proper personal hygiene rules [13,18,21]. Hand washing before handling food and thoroughly cooking all food before eating decrease the risk of getting shigellosis [32].

*C botulinum* is a gram-positive, rod-shaped, anaerobic, spore-forming, motile bacterium with the ability to produce the neurotoxin botulinum [33,34]. The natural habitats of the *C. botuli-*

*num* are soils and marine sediments throughout of the world. Since it is found in the soil, it may contaminate vegetables cultivated in or on the soil. It also colonizes the gastrointestinal tract of fishes, birds and mammals [35]. *C. botulinum* is not a very common bacterium, yet it is very dangerous when it does infect a person [9,18]. Foodborne botulism generally occurs 18 to 36 hours after exposure [range 6 hours to 8 days]. Initial symptoms can include nausea, vomiting, abdominal cramps or diarrhea. After the onset of neurological symptoms, constipation is typical. Dry mouth, blurred vision and diplopia are usually the earliest neurological symptoms. They are followed by dysphonia, dysarthria, dysphagia and peripheral muscle weakness. Symmetric descending paralysis is characteristic of botulism [35]. There are no fever and no loss of consciousness. The symptoms are not caused by the bacterium itself, but by the toxin produced by the bacterium. Incidence of botulism is low, but the mortality rate is high if prompt diagnosis and appropriate, immediate treatment (early administration of antitoxin and intensive respiratory care) are not given. The disease can be fatal in 5 to 10% of cases [36]. Because it is an anaerobic bacterium, it can only grow in the absence of oxygen. Foodborne botulism occurs when *C. botulinum* grows and produces toxins in food prior to consumption. The growth of the bacteria and the formation of toxin occur in products with low oxygen content and certain combinations of storage temperature and preservative parameters. Canned foods improperly prepared and heated and particularly low-acid foods, such as green beans, spinach, mushrooms, meat and vegetables, are very risky in regard to *C. botulinum* contamination [9,18]. Occasionally, commercially prepared foods are involved. Though spores of *C. botulinum* are heat resistant, the toxin produced by bacteria growing out of the spores under anaerobic conditions is destroyed by boiling (for example, at internal temperature >85°C for 5 minutes or longer). Therefore, ready-to-eat foods in low-oxygen packaging are more frequently involved in botulism [36]. Food inside cans that are deformed or warped should under no circumstances be consumed [9,18]. Prevention of foodborne botulism is based on good practice in food preparation, particularly preservation and hygiene. Botulism may be prevented by the inactivation of the bacterial spores in heat-sterilized or canned products or by inhibiting bacterial growth in other products. Commercial heat pasteurization may not be sufficient to kill all spores, and therefore the safety of these products must be based on preventing bacterial growth and toxin production. Refrigeration temperatures combined with salt content and/or acidic conditions will prevent the growth of the bacteria and formation of toxin [18,35,36].

*E. coli* is a gram-negative, facultative anaerobic, rod-shaped bacterium [18]. *E. Coli 0157:H7* is a very common bacterium found in the human intestines [9]. Provided resource availability and key abiotic conditions (availability of energy and nutrient sources, pH, moisture and temperature) are propitious, *E. coli* populations can survive and even grow in open environments such as soil, manure and water. There are also possibilities for migration between these habitats [37]. Whether food is prepared at home, in a restaurant or in a grocery store, unsafe handling and preparation can cause contamination. Common causes of food poisoning include failing to wash hands completely before preparing or eating food, using utensils, cutting boards or serving dishes that are not clean, causing cross-contamination, consuming dairy products or food containing mayonnaise that have been left out too long, consuming foods that have not been stored/cooked at the right temperature, especially meats and poultry, consuming raw seafood products, drinking unpasteurized milk and consuming raw produce

that has not been properly washed *[38].* Fecal contamination of water or foods is responsible for causing the infection [39]. It can be conveyed through raw or undercooked minced meat or unpasteurized milk. Infection by this bacterium can cause hemolytic–uremic syndrome, which can cause bloody colitis with severe abdominal pain, bloody diarrhea, nausea and vomiting, and the syndrome can lead to renal failure, brain damage, heart attack, paralysis and even death [9]. People with weakened immune systems, pregnant women, young children, and older adults are at increased risk for developing these complications [38]. Person-to-person contact is an important mode of transmission through the oral-fecal route. The duration of excretion of EHEC is about 1 week or less in adults, but can be longer in children. Visiting farms and other venues where the general public might come into direct contact with farm animals has also been identified as an important risk factor for EHEC infection [39]. To protect against contamination, the meat should be cooked very well and foods that include meat should be prepared in perfectly hygienic conditions [9]. The prevention of infection requires control measures at all stages of the food chain, from agricultural production on the farm to processing, manufacturing and preparation of foods in both commercial establishments and household kitchens [39].

*Campylobacter* is a gram-negative, microaerophilic, non-fermentative bacterium. It grows best in habitats with an oxygen level lower than 5%, and it is typically found in the intestinal tract of animals. They are able to move via flagella. The optimum growth temperature is 42–45 °C and they cannot proliferate in room temperature [16]. *Campylobacter* is one of the bacteria most frequently responsible for causing gastroenteritis. While its actual incidence is not known exactly, in high-income countries, its incidence ranges between 4.4 and 9.3 in every 1000 people each year *[27]*. The infection can pass through animal-sourced food, particularly those of flying bird species, domestic animals, such as cats and dogs, contaminated surface streams, unpasteurized milk and direct physical contact with infected animals. Infection from this bacterium leads to foodborne diseases usually through uncooked meat and other products and raw or unpasteurized milk. Contaminated water and ice are also sources of infection [39]. *Campylobacter jejuni* can be found in both fresh water and sea water and can live for 5 weeks in this environment. Wild birds, farm animals, farm areas and surfaces of still waters create an ideal ecological system for different types of *Campylobacter*. The presence of this microorganism in nature indicates that fecal contamination has occurred in that area. These microorganisms are unable to survive and reproduce anywhere except for in their hosts, and they die in sunlight. Contamination occurs in the environment and on other animals particularly through the droppings of wild birds, such as ducks, geese and seagulls [21]. The most frequent symptoms associated with this infection are Guillain-Barre syndrome (GBS), reactive arthritis (ReA) and irritable bowel syndrome (IBS) *[27].* To prevent its infection, it is necessary to take protective measures in all stages of the food chain, from production to consumption, and to apply these protective measures in both industrial and domestic environments [39].

*B. cereus* is a gram-positive, rod-shaped, soil-dwelling, facultative anaerobic bacterium. It can grow between 10 and50 °C, but the optimum growth temperature is 28–37 °C. It can be destroyed at the boiling temperature in 5–30 minutes [16]. *B. cereus* is present in dust and soil and can cause contamination in cereals, particularly those made of rice, in food that sits out

for a long time and in meat products [19,21]. The microbe is able to grow either in the presence or in the absence of oxygen. Its spores are sufficiently heat resistant to survive pasteurization treatment of milk and standard cooking temperatures reached in domestic kitchens. It cannot survive the high-temperature treatment used to process canned foods. The symptoms start after 30 minutes of ingestion. Firstly, nausea and vomiting can be seen and then diarrhetic syndrome generally starts [40]. In case of foodborne illness, the diagnosis of *B. cereus* can be confirmed by the isolation of more than 105 *B. cereus* organisms per gram from epidemiologically implicated food, but such testing is often not done because the illness is relatively harmless and usually self-limiting [41]. To prevent infection, foods should be washed thoroughly, not left at room temperature for a long time after being cooked and not left in an open container on the kitchen floor [19,21].

*Giardia duodenalis, Cryptosporidium parvum, Cyclospora cayetanensis* and *T. gondii* are the parasites that pose the biggest threat to food safety. *G. duodenalis*, previously called *Giardia lamblia*, and now commonly known as "intestinalis", is a microscopic parasite, which lives in human and animal intestines. It usually infects people through contaminated water and uncooked meat. The parasite attaches to the epithelium by a ventral adhesive disc and reproduces via binary fission. The most frequent symptoms associated with this parasite are diarrhea, abdominal cramps, gas and nausea. Giardia lamblia is difficult to detect, which often leads to a delay in diagnosis or misdiagnosis; several tests should be conducted over a 1-week period. Giardiasis is a global disease that infects nearly 33% of people in developing countries and 2% of adults and 6–8% of children in developed countries worldwide. It is especially important that proper hand hygiene be practiced for protection against this parasite [42].

*C. parvum* is a unicellular microscopic parasite protected by a shell. It is responsible for causing the disease cryptosporidiosis, also known as "Crypto", and it is the main cause of worldwide diseases originating from water and food. Generally, it infects people through soil, foods, water and infected animal parts that had contact with feces. Its most widespread symptoms are diarrhea, abdominal cramps, upset stomach and mild fever. Some cases, however, may not cause any symptoms. In order to protect against this parasite, proper personal hygiene should be performed, only clean water should be used for drinking and vegetables or fruits that have been fertilized with unprocessed fertilizer should not be consumed [42]. This parasite is transmitted by infected food handlers or processors' contact to the food or by foods produced with using animal feces as a fertilizer. When the parasite is involved, watery diarrhea is commonly seen as the main symptom. There is no known effective treatment method. [17].

*C. cayetanensis* is a unicellular microscopic parasite that causes cyclosporiasis. Although the incidence of cyclosporiasis is reported to be increasing in many countries, this organism is not very well known. In the incubation stage of the parasite, *C. cayetanensis oocysts* infect people through the consumption of water contaminated with this parasite or by eating anything that has come into contact with the feces of an animal with cyclosporiasis disease. The disease may cause symptoms such as diarrhea, loss of appetite, abdominal ventricosity, nausea and vomiting. To protect against infection from this parasite, it is necessary to perform proper personal hygiene and to wash or peel vegetables and fruits before eating them [43].

*T. gondii* is a unicellular microscopic parasite that causes toxoplasmosis disease, and it exists all over the world. It is among the top three causes of death from foodborne diseases worldwide. It can infect people through the consumption of uncooked meat or by drinking from fresh water sources, such as lakes or streams. This parasite can also infect the fetus through the mother. Moreover, as cats are major hosts for *T. gondii*, domestic cats should receive proper cleaning and hands must be washed after handling them. Symptoms associated with infection from this parasite include diarrhea, upset stomach, vomiting and abdominal pain [44]. In food-caused toxoplasmosis cases, *T. gondii* infects people through consumption of uncooked or undercooked meats. Especially, this parasite spreads faster by products that are contaminated with cat feces. With the higher consumption of raw meats, it shows increased prevalence in Europe and South Africa. *Toxoplasma* infections can be diagnosed by response of antibodies with serologic applications [17].

Infections caused by microorganisms are largely the result of the poor hygiene of the person responsible for preparing the food. These microorganisms can rapidly reproduce in temperatures outside the safe ranges specified by food safety regulations [1].

Cooked foods should not be left to sit in room temperature for longer than two hours. These foods should be cooled rapidly and kept refrigerated, preferably at a temperature under 5°C. Microorganisms can reproduce very rapidly at room temperature. Temperatures below 5°C and above 60°C cause the reproduction of microorganisms to slow down or stop. Table 1 presents the measures that should be followed to ensure food safety [1].

| Step | Danger | Measure |
|---|---|---|
| Supply/Purchase | Contamination of raw foods | Purchase foods from reliable suppliers.<br>Make sure that hygienic conditions are provided and maintained during supply and transportation. |
| | Contamination of ready-to-eat foods | Purchase foods from reliable suppliers.<br>Purchase foods from companies that apply HACCP* system. |
| Storage | Contamination | Keep foods in wrapped or closed containers.<br>Perform pest control. |
| | Reproduction of bacteria | Monitor the time and temperature of storage.<br>Follow the FIFO** principle. |
| Preparation | Contamination resulting from personal hygiene | Wash hands before touching the food.<br>Prevent cross-contamination by surfaces and containers.<br>Separate cooked foods from raw foods.<br>Use boiling water, especially if the food will not undergo additionally cooking. |
| | Reproduction of bacteria | Pay close attention to the amount of time foods remain at room temperature. |

| Step | Danger | Measure |
|---|---|---|
| Cooking | Survival of the pathogen | Make sure that the food is cooked well (the food in its entirety should have a temperature of 70°C) |
| Cooling and keeping at cool temperatures | Reproduction of the bacteria and spores which did not die in high temperature; toxin production | Make sure that the temperature of the food drops below 5°C as soon as possible when cooling it.<br>Do not let foods remain at room temperature longer than two hours.<br>Avoid storing too much food in the refrigerator or in the cool spaces in it.<br>Beware of the thermal agitations in long-term cold storage. |
| | Contamination by various sources | Wrap the foods appropriately and prevent their direct or indirect contact with raw foods<br>Make sure that the food containers are clean when storing the cooked foods. |
| Waiting in high temperature | Reproduction of the bacteria and spores which did not die in high temperature; toxin production | Keep temperature of the food above 60°C. |
| Re-heating | Survival of the bacteria | Re-heat the food properly. |
| Service | Reproduction of bacteria, production of spores, and toxins | Re-heat the food properly. |
| | Contamination | Do not touch the food with hands.<br>Serve the food hot.<br>Prevent contact between uncooked foods and unclean containers. |
| *HACCP: Hazard Analysis Critical Control Point<br>**FIFO: First In First Out Method | | |

**Table 1.** Measures to Be Followed to Ensure the Provision of Food Safety [45]

## 2.2. Personal Hygiene of Food Handlers

The food processing stage is one of the most important stages in the food chain, and those responsible for performing the duties involved in this stage assume major responsibilities in the prevention of food poisoning cases [46,47]. The food processing staff should include healthy individuals who do not have any diseases, and they should undergo regular medical check-ups. In addition to being healthy, it is also important that the workers take particular care for their personal hygiene and execute proper food handling behavior. This is especially important because food handlers can cause cross-contamination between raw and cooked foods, and they may jeopardize food hygiene by improper preparation, cooking and storage of foods [47]. A study confirmed by the Food and Drug Administration (FDA) determined that

81 foodborne diseases were caused by foods contaminated via food processing workers [48]. It should be noted that food workers have the power to make a remarkable impact on public health. In reducing the foodborne diseases or food poisoning, the personal hygiene practices of workers at food production sites are a key factor [49]. It is well known that proper personal hygiene is the best way to mitigate the risks associated with contamination by most of the bacteria generally seen as being responsible for foodborne diseases (Table 2) [40].

| Pathogen | Foods involved/sources | Prevention |
|---|---|---|
| Campylobacter | Unpasteurized dairy, poultry and meats, infected food handler | Cook all foods thoroughly. Use only pasteurized dairy products. Wash hands properly. |
| Hepatitis A | Water, ice, shellfish, salads, cold cuts, sandwiches, fruits, fruit juices, milk, milk products, vegetables, any food that will not undergo further heat treatment | Purchase shellfish from approved suppliers. Prevent cross–contamination through hands. Ensure food handlers practice proper hand washing, and prevent bare hand contact with food. |
| Norovirus | Raw fruit, raw vegetables, prepared salads, raw shellfish | Cook foods thoroughly. Wash hands. Use certified shellfish. No bare hand contact with food. |
| (Staph) *S.* aureus | Ready-to-eat foods, i.e., sandwiches, salads, ham and other meats, potato salads, custards, warmed-up foods; food handlers' infected cuts, throat, nose and acne | Practice proper hand washing and hygiene. Avoid cross-contamination. Keep bare hand contact with foods to a minimum. Prohibit workers who have cuts and lesions from handling the food. Cool foods rapidly. |
| Salmonella | Undercooked or raw meats, poultry & shell eggs, poultry and egg salads, egg custards and sauces, protein-containing foods, pets and infected food handlers | Avoid cross-contamination. Cool and refrigerate foods immediately. Cook meats / poultry thoroughly. Practice proper hand washing. |
| Shigella | Ready-to-eat foods associated with bare hand contact (salads, sandwiches, etc.), source: human feces and flies | Practice proper hand washing after using the bathroom. Use only approved water and foods Control flies. No bare hand Contact with food. |

**Table 2.** Pathogens that threaten food hygiene, the foods they infect and preventive measures

In the Codex Alimentarius [50], the topics involving workers at food processing sites and food hygiene were classified under the following titles: **Health status, Illness and injuries, Personal cleanliness** and **Personal behavior**.

Persons who have any disease that may cause food infection or persons who are suspected to be hosts should not be allowed into the food processing site. Workers at food processing sites who have any symptoms associated with infections should be reported to the administration, and they must be examined by a physician [50]. Accordingly, the law that entered into force

in Turkey in 1996 includes the provision: "The staff to be hired to work in the processing of foods and food additives cannot be employed without first providing a medical report. Those who are determined to be carriers should immediately be treated. Those who do not obtain a clean bill of health after completing their treatment should definitely not be employed. The owner or administrator of the workplace is responsible for ensuring that the workplace is in compliance with all of these practices" [51]. Similarly, it is reported that in certain regions in the United States, workers at food processing sites are required to show a health card to their employers [52]]. In the WHO consultation report, routine medical and microbiological examinations of food handlers are not generally recommended, but if food handlers are suffering from an illness that includes symptoms such as jaundice, diarrhea, vomiting, fever, sore throat, skin rash or skin lesions, like boils or cuts, they should report this to their supervisor before starting work [53]. If workers have a sore throat or fever, open cuts or infected wounds, Norovirus, diarrhea, vomiting or jaundice or if they have had contact with someone who has *Salmonella typhi, E. coli 0157:H7, Hepatitis A* or *Shigella,* they should immediately be removed from the food production sites. The employer must take the necessary precautions within 24 hours and report these workers to the relevant institutions. Many studies have recommended that food production sites include health service units and that it was important that workers report their diseases [54–57].

The hygiene practices that should be performed by food processing workers include precise adherence to personal hygiene regulations and the wearing of special, protective attire such as bonnets and gloves to help secure their hygiene. It is important that these clothes be regularly cleaned and cared for [50]. Reports have shown that the lack of personal hygiene among workers at food processing sites was among one of the practices that contributed to food borne diseases and that proper hand washing was the most commonly neglected practice. The practice of improper hand washing may be an important factor in the spreading of foodborne diseases by cross-contamination. It was reported that of the staff working in food production sites, 60% did not wash their hands correctly, and of the foodborne diseases, 25 to 40% were linked to staff working in food processing and food services industries [58,59]. It was also reported that food processing and food service workers were the asymptomatic carriers of the pathogens which caused food poisoning, due to their failure to wash their hands properly after using the restroom [60]. Another study determined that the foods became infected due to improper cleaning of contaminated hands after using the restroom [61]. Aycicek [62] took samples from bare hands and hands with gloves during the food preparation stage (180 in total) and found that the bacteria load on bare hands was significantly higher than that of the gloved hands ($p < 0.05$). The most common bacteria found were *S. aureus* (126/180), *Bacillus spp.* (19/180) and *E. coli* (14/180).

In addition, many studies have reported that workers in the food processing industry did not show enough care in washing their hands properly when necessary and in using protective attire (e.g., gloves, bonnet) [63–66].

The situations when workers should wash their hands are summarized below.

- Before starting to prepare food

- Before touching unpacked foods and clean equipment
- Before serving the foods and touching the clean utensils and equipment
- Before changing tasks from raw meat to ready-to-consume foods in order to prevent cross-contamination during food preparation practices
- After touching any part of the body
- After using the restroom
- After coughing, sneezing or using a handkerchief
- After smoking
- After eating or drinking something
- After touching unclean equipment and tools
- After leaving the kitchen and before entering again
- After washing the dishes
- After touching the handle of the refrigerator, door or any other place commonly used by people during food preparation practices
- After touching working clothes
- Before and after entering areas where foods are kept and stored
- After handling cash
- Before wearing gloves and after taking them off, hands should be properly washed according to hygiene rules [67]

The steps for proper hygienic hand washing are: wash hands and wrists with soap under clean running water, being sure to rub between the fingers; use a nail brush to clean nails; rub arms and wrists with soap and water; soap and rub hands together for 10 to 15 seconds; dry hands with hot air or paper towel and use a paper towel to turn off the tap [63,68]. It is now known that hand-drying methods are as important as hand-washing methods in the prevention of contamination by microorganisms [69]. Studies have demonstrated that among all forms of drying methods, hand dryers posed the greatest threat of contamination. It was found that hand drying machines are less than an ideal alternative for drying hands after they have been washed, as these machines allow the bacteria to be able to spread as far as one meter away; therefore, the use of paper towels should be encouraged [70,71].

In general, humans are the primary source of food contamination, posing a risk to food safety as carriers. Along with the many extraneous factors, such as hands, clothes, accessories, hair and mustache, internally derived factors, such as the breath, spit and wounds, can be sources of contamination. It was reported that food processing workers were capable of spreading 10,000 to 100,000 microorganisms every minute [72,73]. Thus, workers should avoid certain behaviors at the production site, such as smoking, coughing, sneezing, chewing and eating. They also should not wear accessories, watches or hairpins [50].

## 2.3. Kitchen sanitation

Another important issue in the provision of food safety is kitchen sanitation. A study conducted in child care centers in the states of North Carolina and South Carolina in the United States found that most kitchens were not in compliance with the FDA's 2009 Food Code [74]. In order to minimize the risk of foodborne illnesses in the production and processing of foods, it is necessary to minimize the risk of contamination in the placement, arrangement and decking of kitchen utensils, to set up the area so that it is equipped to perform maintenance, repair, cleaning and disinfection and to ensure that surfaces and materials in the kitchen are anti-toxic, that the kitchen has control mechanisms for temperature and humidity, if possible, and that effective measures are taken against pests [50].

### *2.3.1. Kitchen hygiene*

Issues related to kitchen hygiene should be addressed prior to even completing the construction of the kitchen. The plan and interior design of the kitchen should be arranged in such a way as to facilitate proper hygiene practices (e.g., protection against cross-contamination) [50].

The kitchen should be constructed with durable materials that are easy to care for and clean. These materials should be free of any substances that can potentially render the food unsuitable for consumption, such as parasites, pathogenic microorganisms and toxins, or raw materials, food components and others substances used in the production of processed products that have been infected by foreign substances [75].

The surfaces should be designed in such a way as to not accumulate dirt, to prevent foreign substances from infecting foods and to not allow the creation of dense liquids or mold. Pests should also be prevented from entering the workplace. Drainages should be easy to clean and prevent pests such as rodents from entering and waste liquids from re-entering back into the kitchen environment [76].

There should be warnings written and hung on the walls of the workplace about the rules the staff should obey and the best hygiene practices to be performed. The staff should be provided with changing rooms that include a sufficient number of lockers to hold both work and civilian clothes. The staff should not keep any food in these lockers [75].

Ventilation systems should be capable of eliminating smoke, odors, soot and evaporation, keeping heat inside and preventing dust, dirt and pests from entering. Filters and other parts of the systems should be easily accessible for cleaning or changing. The kitchen should have natural or artificial lights that are equal to the natural light of the day, and the intensity and color of the lights should not impact the production or the quality of the foods in a negative way. There should be continuous control on humidity and temperature in the food storage sites [76].

To maintain a hygienic kitchen, the continuity of cleaning and disinfection procedures is as important as the layout plan of the kitchen. Therefore, a cleaning and disinfection plan should be developed for the kitchen, and all cleaning and disinfection practices should be done

according to this plan and recorded. The staff should be trained on the sanitation and disinfection of the kitchen [75].

### 2.4. Equipment hygiene

Equipment that comes into regular contact with foods should be made of material able to be cleaned and disinfected, resistant to corrosion and non-toxic. The equipment should be arranged in a way as to enable it and the area around it to be cleaned sufficiently. When it is necessary that chemicals be used to clean the equipment, the instructions governing the use of those chemicals should be followed. Calibration checks of the equipment and tools should be made regularly, and these checks should be recorded [76].

## 3. Food safety systems

Effective food control systems are needed to improve the applicability and control of food safety [77]. Currently, the HACCP, ISO 22000 and PAS 220 are the most commonly used internationally approved food safety systems.

### 3.1. Hazard analysis and critical control points (HACCP)

HACCP was first used in the 1960s by the American Pillsbury company for the purpose of producing "zero defect" products for the US Army and NASA. Later, starting in the 1970s, it began to be used as a reference by the Food and Drug Administration (FDA) in official supervisions. It was adopted by the Codex Alimentarius Commission in 1992 and published as the HACCP international standard for the first time. Since then, the food industry and official authorities have been using it to protect against and control the risks of potential dangers that could threaten food safety [78].

Initially, HAACCP had three principles:

1. Identification and assessment of hazards associated with food products
2. Determination of critical control points to control identified hazards
3. Establishment of a system to monitor the critical control points

The HACCP, as it is applied today, has five starting steps and is governed by seven principles. The starting steps were created by Codex, and they should be completed prior to implementing the seven HACCP principles. The starting steps help to ensure that the HACCP system is implemented and managed in the most effective way possible [79].

The HAACP system is applicable for any company operating within the food chain, regardless of their size. In the implementation stage, the HACCP system should be supported by certain preliminary condition programs. A company interested in implementing this system should already be following the requirements of this preliminary condition program. Preliminary condition programs include national regulations, codes of practice or other food safety

prerequisites. In general, preliminary condition programs involve factories and equipment, staff training, cleaning and sanitation, maintenance chemical control, waste management, storage and transportation [78].

| Five starting steps | The seven principles of the HACCP system |
|---|---|
| 1. Assemble HACCP team | 1. Conduct a hazard analysis |
| 2. Describe the product | 2. Determine Critical Control Points |
| 3. Identify intended use | 3. Establish critical limits for each CCP |
| 4. Construct flow diagram | 4. Establish a monitoring system for each CCP |
| 5. Conduct on-site confirmation of flow diagram | 5. Establish corrective actions |
| | 6. Establish verification procedures |
| | 7. Establish documentation and record keeping |

**Table 3.** HACCP Implementation in 12 Steps

HACCP is an internationally accepted system and in most countries, it is required that companies within the food industry implement this system.

### 3.2. ISO 22000

In 2005, The International Organization for Standardization (ISO) published a standard for the Food Safety Management System known as ISO 22000. The ISO 22000 system is a combination of preliminary condition programs, HACCP principles and implementation steps defined by the Codex Alimentarius Commission and ISO 9001:2000 standard components. After it was defined, it began to be used in more than 50 countries within 2 years [80].

The basic approach of the ISO 22000 standard is to implement a preventive system that serves to protect consumers from foodborne diseases. This standard controls all the processes in the food chain, including infrastructure, staff and equipment. In business establishments, the Food Safety Management System implementations include production control, product control, equipment control, maintenance, general hygiene practices, staff and visitor hygiene, transportation, storage, product information, training, the selection and evaluation of suppliers, communication and other similar issues [81].

The main goal of this standard is to have a system in place that determines the unacceptable risks that may result from process errors and to secure product safety and consumer health. Food safety supervision over product, design, production and quality control determines and eliminates the potential dangers. The fundamental role of ISO 22000 is not only to provide food safety but also to improve the sensory and nutritional quality of food, and it also plays a primary role in the quality assurance of service practices in industrial production. Lastly, this standard helps to reduce operational losses by instituting a more effective use of resources to increase productivity, and thereby, directs the establishment to a system of total quality [80].

### 3.3. PAS 220 (publicly available specification)

This standard was created by the major global food producers in cooperation with the Confederation of Food and Drink Industries (CIAA) with the purpose of eliminating the weaknesses of the ISO 22000 food safety system standard. Nestle, Unilever, Danone and Kraft, the sector leaders generally known as "G4", collectively published the PAS 220 standard, which refines the preliminary conditions programs. The PAS 220 standard is applicable for all types of companies and was made available in 2008. It was intended that the PAS 220 standard be used together with the internationally accepted ISO 22000 standard [82].

The content and topics of PAS 220 elaborate on the 10 sub-titles in the ISO 22000 standard and adds 5 of its own, resulting in the following 15 items [82]:

- Structure and placement of buildings
- Placement of work site, buildings and their wings
- Supporting plants (air, water, energy)
- Supporting services, including wastes and sewage
- Adequacy of the equipment, cleaning and preventive care
- Management of purchased materials
- Measures against cross-contamination
- Cleaning and sanitation
- Pest control
- Staff hygiene and workers' lodgings
- Re-processing
- Product recall procedures
- Storage
- Informing consumers about products
- Food defense, biodefense and bioterrorism

## 4. Good agricultural practices

Today, increasing attention is focused upon the impact farming practices are having on the environment, and there is an increasing emphasis on more sustainable methods of crop production. Systems need to be adopted that are more sensitive to environmental issues, genetic diversity, wildlife and their habitats and in some cases the social structures of rural communities. Furthermore, consumers around the world are more sophisticated and critical

than in the past, demanding to know how and what has been used to produce their agriculturally derived products.

Good Agricultural Practices (GAP) are defined "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products" by the FAO. The aims of the GAP are as follows:

- Ensuring agricultural production harmless to environment, human and animal health
- Safety of natural resources,
- Ensuring traceability and sustainability in agriculture,
- Improving workers health and working conditions,
- Ensuring safety and quality of produce in the food chain.

General principles for GAP were first presented to the FAO Committee on Agriculture (COAG) in 2003 in the paper "Development of a Framework for Good Agricultural Practices" the annex of which broadly outlined farm-level GAP recommendations in 10 fields; which are "soil", "water", "crop and fodder production", "crop protection", "animal protection", "animal health and welfare", "harvest and on-farm processing and storage", "energy and waste management", "human welfare, health, and safety" and "wildlife and landscape".

Although there are some GAP used by different organizations to succeed different purposes and goals, GLOBALGAP (EUREPGAP) is the widespread certificate in agricultural produce worldwide. GLOBALGAP documents consists of; ISO 9001:2000 Quality Management System, ISO 14000 Environmental management system, OHSAS 18001 Work Health and Safety Management System and ISO 22000 Food Safety Management System principles [83].

## 5. Conclusion

Food safety ultimately deals with the consumption stage, where the existence and level of the dangers caused by foods are of chief concerns. The observance of rigorous control procedures throughout the course of the food chain is a fundamental necessity, given that risks to food safety can surface in any stage of the chain. Therefore, all parties involved in the food chain share the responsibility for ensuring food safety.

The design of a food safety system involves numerous factors. To begin with, minimum hygiene standards should be determined by laws and regulations, food producers must apply food safety measures and procedures and official bodies must supervise and inspect food industry companies to confirm that they are conducting their operations in a manner consistent with the regulations in force. Food poisoning cases that threaten public health globally occur as a result of the contamination of foods in any stage, from production to consumption. Although the factors jeopardizing food safety seem to be easy to control in theory, studies and current practices indicate that there is still a long way to go in practice.

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