Microbiological Contamination Of Food: The Mechanisms, Impacts And Prevention

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Abstract: Food growers, handlers and consumers, beware! Food, the basic need of man can cause devastating impacts if contaminated with pathogenic microorganisms/microbial toxins. The reliable supply of safe food that is free from harmful contaminants is important for the people's general health and daily life, economic development and social stability and the government and countries' image. One way to protect a population from all the detrimental impacts of food microbiological contamination is to spread information and knowledge about the sources and routes of transmission of pathogens into food. This paper review thus addressed the microbiological contamination of foods including the mechanisms of microbiological contamination, microbial contaminants and their commonly associated foods, impacts of microbial contamination of food and their prevention and control. The paper also gave some hints on certain foods to avoid in order to evade food poisoning. Stay alert, follow proper procedures and enjoy your food, health and food business.

Keywords: Alert, Food safety, Food poisoning, Impacts, Mechanisms, Microbiological Contamination, Prevention and Control

1 INTRODUCTION

According to Codex Allimentarius, food is any substance, whether processed, semi-processed or raw which is intended for human consumption including chewing gum and any substance that has been used in the preparation or treatment of "food" but excluding cosmetics, tobacco and substances used only as drugs. The importance of food can never be over-emphasized [13]. Food meets a basic physical need. To this effect, food has been defined as edible or portable substances (usually of plant or animal origin) consisting of nourishing and nutritive components such as carbohydrates, fats, proteins, essential minerals and vitamins which (when ingested and assimilated through digestion) sustains life, generates energy and provides growth, maintenance and health of the body [16]. Besides, food also meets emotional, social and psychological needs. **R**egrettably, foods despite their beneficial roles in the body, can also serve as vehicles for disease transmission and cause of death if contaminated with harmful microorganisms, microbial toxins or environmental contaminants (chemical allergens and Microphysical particles).

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An adequate supply of Safe, wholesome and healthy food is essential to the health and wellbeing of humans. This is in keeping with the phenomenon of food security, defined by Food and Agricultural Organization (FAO) of the United Nations (UN) as " Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life [23]. Thus, besides assuring that all people have access to enough food to lead productive lives, food security also has the challenge of assuring that the food is safe from a chemical, physical and biological aspect. This aspect of food security is called food safety (an umbrella term that encompasses many facets of handling, preparation and storage of food to prevent illness and injury) including chemical, microphysical and microbiological aspects of food quality [31]. Microbiological aspect of food safety involves exclusion from food, of pathogenic microorganisms or microbial toxins which presence in food could constitute potential health hazards. This implies prevention / management of Microbiological contamination of food which in turn refers to the non-intended or accidental introduction into or inclusion of harmful microorganisms or microbial toxins in food, making it unsafe for consumption. Many opportunities exist for food to get contaminated along the food chain (from production to dining table). A review of the medical literature has shown that microbiological contamination is more common than both chemical and microphysical contaminations. The relative number of illness due to foodborne microorganisms makes microbiological quality the most important food safety factor [27], [60]. Food contaminated by pathogens or chemical substances is a serious issue because it can lead to a wide range of health problems. This is responsible for more than 200 diseases, including typhoid fever, diarrhea and cancers, among others [78] and can lead to the death of unsuspecting consumers in both developing and the developed countries [55]. Besides diseases and death, the consumption of pathogen-contaminated foods also creates economic impact that can be quite devastating on the consumers, a nation, food dealers and food companies. Literature is replete with reports on incidence and outbreak of diseases and hospitalizations, cases of people that have experienced unquantifiable pains from ill health, loss of lives to death, huge unexpected expenditure and unimaginable financial losses incurred by

many individuals, food vendors, food companies and some nations and many food businesses losing their reputation and even their business [5], [58], [9], [11], [12], [20], [26], [28], [30], [5]. Each of these cases was traced to consumption of food tainted with harmful microbial contaminants The reliable safe food supply that is free from harmful contaminants is important for the people's general health and daily life, economic development and social stability; the government and countries' image. The greatest challenge to protect a population from foodborne diseases is to spread information and knowledge about the sources and routes of transmission of pathogens into food [40]. The exclusion and control of these well-estimated risk factors help to develop safe food all over the world and reduce the socioeconomic burden of foodborne diseases. This review is therefore an attempt to provide alert on microbiological aspect of food safety as it concerns the different microbiological contaminants and their commonly associated foods, the mechanisms by which foods get contaminated by pathogens, the impact of pathogen inclusion or growth in food and ways to protect foods and customers against microbial contamination and food poisoning respectively. Some hints on certain foods to avoid in order to evade food poisoning, is also provided.

2.0 MECHANISMS OF MICROBIOLOGICAL CONTAMINATION OF FOOD

2.1 Introduction

It takes several steps to get food from the farm to the dining table. This step is called the food production chain. Many opportunities exist for food to get contaminated along the chain [39]. Microorganisms including pathogens can be introduced to the crop or food animals during primary production (in the farm where plants are grown or animals are raised for food (pre-harvest or pre-slaughter stages), at harvest and slaughter of food produce and food animals respectively and at postharvest/ post-slaughter (consisting of food processing, distribution and marketing, storage, preparation and serving). **P**athogenic microbes can potentially be found more or less everywhere; from where they directly or indirectly get introduced into food. Some are sustained in human reservoirs and contaminate the food supply via the excreta of infected humans. Many others are sustained in animal reservoirs and contaminate the food supply because they are present in the flesh, milk or eggs in the living animal or because they are in excreta of infected animals that subsequently contaminate the foods we eat. Some persist in the environment or in multiple hosts and can contaminate the foods we eat via pathways that reflect the variety of ecosystems that make up our food supply. Food safety depends on understanding these pathways or mechanisms well enough to prevent them. The different mechanisms or pathways through which pathogenic microorganisms or microbial toxins get into food are hereby presented under preharvest/harvest contamination, preslaughter/slaughter contamination and post-harvest/post slaughter contamination.

2.2 Pre-harvest/Harvest Contamination of Food

Outbreak investigation shows that contamination events often start with problems in production, that is, while growing the plants that are harvested or raising food animals.

2.2.1 Pre-harvest Factors

While being grown in the field, plant foods can get contaminated with microorganisms, pathogens inclusive through water used for irrigation and application of pesticides, manure applied as fertilizer, migratory or feral animals and practices of workers in the field. However, water used for irrigation and application of pesticides and manure applied as a fertilizer form the two most important sources of pathogens prior to harvest [5].

I. Water used for irrigation and application of pesticides

Contaminated water used for irrigation has been suspected as the likely cause of contamination of outbreaks of E. coli 0157:H7 infection traced to lettuce (Hilborn et al., 1997), and tomatoes and mangoes with salmonella (Brown et al., 2006; Hedberg et al., 1999: Green et al., 2008). A study conducted in crops (Lettuce, Carrots and Amaranthus) was positive for Salmonella, Vibrio spp and E. coli following irrigation with water that also tested positive for the same pathogens [51]. Research has shown that the method of application of irrigation water directly influences whether the organisms can be found associated with the edible portion of the plant at harvest [67].

II. Manure applied as fertilizer

Research has shown that certain pathogens e.g. E. coli 0157:H7 can develop acid resistance and survive in low pH environment such as the human stomach acid, colon of grain feed animals. A number of studies have demonstrated the long term survival of E. coli 0157.H7 and salmonella in manure [51], [35]. According to Kudva et al., E. coli 0157:H7 survived for 21 months in manure that has been collected from experimentally inoculated sheep and held outside fluctuating environmental conditions. Manures from these animals or untreated domestic sewage may contain these acid resistant pathogens and if used to fertilize plant crops and with improper application time prior to harvest or improper composting, may lead to contamination of raw plant foods should they touch the soil [17].

III. Migratory or feral animals

Pre-harvest contamination of produce can also take place through migratory or feral animals. Outbreak investigations have revealed direct link between produce and animal reservoirs. Several recent produce-associated outbreaks have followed wildlife intrusion into growing fields or fecal contamination from nearby animal production facilities that likely led to produce contamination. According to the Center for Disease Control [10], a multi-state outbreak of approximately 200 illnesses with E. coli 0157:H7 infection from 26 states was linked to the consumption of fresh spinach. Animal intrusions have also been suspected as the likely cause of contamination of apples in cider orchards by cattle or deer with E. coli 0157:H7 and Cryptosporidium [11], strawberries by deer with E. coli 0157:H7 [36] and Lettuces by wild animals with Yersinia pseudo-tuberculosis in Finland [49]. Feral animals were shown to carry campylobacter and other human bacterial pathogens [34].

IV. Unhygienic practices of workers in the field

Plant foods also get contaminated at pre-harvest through unhygienic practices of workers in the field.

2.2.2 Harvest Factors

At harvest, plant produce get contaminated with pathogenic microorganisms through several mechanisms one of which is through the harvesting equipment of workers. Microorganisms including pathogens can build up in improperly washed and sanitized harvesting equipment such as knives, chippers and containers including trailers, boxes, bins and truck beds, and from where pathogens can spread from a single contaminated commodity to an entire content. Automated equipment can similarly contaminate potentially all crops harvested from a given field and can also spread pathogens from field to field if the equipment is not cleaned and sanitized before moving from one field to the next. Microbial contamination of plant produce also occurs through the hand of field workers. The majority of farm that grow fruits and vegetables harvest by hand. The contaminated unwashed hands of workers contribute to the microflora of fruits and vegetables during harvest. This makes field workers' hygiene integral for ensuring the microbiological safety of fresh produce.

2.3 Pre-Slaughter and Slaughter Contamination

For meat and poultry products, what happens in farms where food animals are raised, in feed lots, during transport and lairage before slaughter as well as during slaughter and further processing can have a major effect on the microorganisms that contaminate food after slaughter and on human health [44]. The feeding of infected foodstuffs to poultry can result in large numbers of chickens and their eggs carrying food poisoning bacteria [17]. Other ways poultry flocks may be infected are through drinking water, rodents, insects, dogs, cats and human stools, footwear, work cloths. Bacteria and other microbial pathogens in animals or from humans or farm equipment can contaminate the environment in which animals are raised, where they roam and where they are kept while awaiting slaughter. Poultry farms with large population of birds are a setting where microbial pathogenic contaminants can spread rapidly [29]. As a result, animals carry bacteria in their skins or hides and in their intestines. From animal skins or hides and the environment, especially where care is not taken in removing the hide, such pathogens find their way into meat or poultry during slaughter and may cross-contaminate other foods that come in contact with the raw contaminated meat or poultry. When birds are slaughtered, hot water dips help remove feathers but can spread intestinal contents to subsequent carcasses. For e.g., Campylobacter jejunii/coli, a common cause of illness in the United States, contaminated at least 40% of chicken breasts at retail [25]. Meat and poultry also get contaminated at slaughter during evisceration (the removal of the offal) where the stomach or intestines may burst; releasing bacteria which can contaminate the flesh (the raw meat or poultry prepared for human consump**tion)** [64]. A small amount can taint an entire batch and spread E. coli 0157:H7 commonly found in animals but deadly when consumed by humans. The evisceration of chickens or turkeys by the same machine or knife can lead to the transfer of pathogenic contaminants such as campylobacter and salmonella from one infected bird to several others. Use of other contaminated slaughtering equipment or slaughter surfaces could be a source of microbial contaminants to meat or poultry during slaughter.

2.4 Post-Harvest/Slaughter Contamination

2.4.1 Food processing/ food preparation factors

Food processing and preparation are both practices used to make a change to a food to alter its eating quality or shelf life. People process foods everyday while preparing meals for their families. For example, the milling of wheat into flour or fermentation of maize into 'ogi' is food processing whereas cooking the wheat in the kitchen or cooking and mixing the 'ogi' with other ingredients are part of their preparation for consumption. However, the term food processing is broader than preparing and cooking foods. It involves applying scientific and technological principles to preserve foods, by allowing changes to the eating quality of foods to be made in a predictable and controlled way [71]. Modern food processing is sometimes defined as taking place at a plant or factory [71]. This is distinct from food preparation which usually takes place in kitchens. However, many activities (such as cooking, washing, slicing, peeling, juicing, shredding, mixing etc.) and use of several equipment are common to both processing and food preparation [45]. Food preparation or processing, whether in the home, at a restaurant or quick service, other types of food service quality (such as cafeteria, nursing home or hospital) or food companies or industries can introduce pathogens into a product if not done properly (Karl, 2001). This is possible through a process of cross-contamination defined as the physical movement or transfer of harmful microorganisms or microbial toxins from one food to another either directly (food to food) or indirectly (equipment/utensils or food contact surfaces to food and people to food). Pathogenic microorganisms can be found more or less everywhere and consequently may be found in raw foods, e.g. meant or poultry to be cooked prior to consumption. L. monocytogenes can be transferred from processing surfaces to foods [32]. Though thorough cooking of such fresh foods will render the small numbers of microbes harmless, it then constitutes a danger when microbes are spread from raw or contaminated food to another food, especially ready-to-eat prepared dishes.

Food contact equipment factors

One important factor of microbial contamination during food processing and preparation is food contact equipment which may harbor and introduce pathogens into food. Processes such as trimming, slicing, milling, shredding, peeling mechanical abrasion and various methods of disintegration if done with contaminated equipment may introduce contaminants from the equipment involved. When cutting boards used for raw meat, poultry or seafood come in contact with other foods, microorganisms can be transferred. Another example is slicing ready-to-eat produce, e.g. lettuce with a knife previously used to cut raw poultry without proper washing and sanitation of the knife in between the processes. Other equipment such as conveyor belts and aprons, filters, blanchers, presses, screens and wooden surfaces are difficult to clean and sanitize and therefore are especially likely to be sources of contamination. Listeria monocytogenes has been found on equipment and process surfaces, which are difficult to clean [77].

Unhygienic practices of food handlers

Another avenue through which foods get contaminated during processing and preparation is infected food handlers and their unhygienic practices [32]. Humans (their skin, mucous membranes and cuts, open sores or a skin infection) can serve as reservoirs of pathogens, e.g. S. aureus and from where foods get contaminated if handled under unhygienic condition, especially through unwashed hands [55]. Direct contamination can happen by contact between the body and the food product. In indirect contamination, people act as vectors and transfer contamination from one area or surface to another [32]. When infected food handlers fail to wash their hands after using the toilet, handling raw meat poultry or fish, taking out garbage, cleaning up spills, handling money, touching other contaminated surfaces such as blemishes, pimples, the nose, boils, open wounds and soiled tissues, food contamination takes place. Viruses such as hepatitis A and Norwalk are easily transmitted to shellfish, salads, vegetables and fruits when infected food handlers fail to wash their infected or contaminated hands. Failure to wear gloves or touching contaminated surface even while wearing gloves, sneezing or coughing into a gloved hand, food, food contact equipment or surfaces are ways foods also get contaminated during processing and preparation. Handlers who do not wear gloves commonly spread Staph bacteria to meat, cream-filled desserts, potato salads and egg products.

Biofilm formation

During food processing, microbial communities including pathogens can inhabit or accumulate on critical places such as food contact and environmental sites on equipment to form biofilms (microbial cell clusters with a network of internal channels or voids in the extracellular polysaccharide and glycoprotein matrix, which allows nutrients and oxygen to be transported from the bulk liquid to the cells). Microbes inhabiting contact and environmental sites in food processing are mostly harmful. The biofilms contribute to food contamination, especially in foods passing through the same processing line where the process equipment is not hygienically integrated in the process line or the cleaning and disinfection procedures are not properly designed to remove the organic soil from the process surfaces [76]. Any microbe can form biofilm under suitable conditions. However some microbes naturally have a higher tendency to produce biofilm than others. Foodborne pathogens that readily form biofilms include Bacillus cereus, S. aureus, M. paratuberculosis, C. perfringens, E. coli 0157:H7, S. typhimurium, C.jejunii, Yersinia enterocolitica and L. monocytogenes [77]. L. monocytogenes has been found to form biofilms on common food contact surfaces e.g. plastic, polypropylene, rubber, stainless steel and glass. Also inclusion of decayed parts of foods e.g. fruits increases the numbers of microorganisms in such food products such as fruits juices.

Use of poor wash water

Prior to reaching the consumer, most foods, especially fresh produce are washed at least once and usually several times during processing. Raw water contains bacteria. Most water supplies are sourced from rivers and lakes which can be contaminated by run-off from land, sewage and slurry. Use of poor water for washing in food processing and preparation can introduce microorganisms into food.

2.4.2 Packaging factors

Packaging serves as a major defense against external hazards. However undesirable interactions between packaging material and food can give rise to potential problems. The risk connected to packaging material is the potential transfer of food spoilage or pathogenic organisms to the packed food. Most packaging materials have proven to be completely impervious to microorganisms. A low number of bacteria in the packaging material could be of concern for e.g. aseptic foods; if bacteria migrate across the package. The routes of contamination from the packaging material to food include the surface, cutting dust or direct contact with the raw edge of the paperboard [37].

2.4.3 Distribution, marketing and storage factors

These also play important roles in microbial contamination of food. Contamination can occur via storage in the market in contaminated bins and other containers, possible contact with decaying products. During food storage in the refrigerator, cross contamination takes place when, for e.g., juice from raw meat, poultry or fish drips onto vegetables or other ready-to-eat foods on the shelf below. Inclusion of raw foods with ready to eat foods during shopping or storage leads to cross contamination. Contamination also occurs when foods are not kept at the right temperature, thus promoting the temperature danger zone (i.e. the temperature in which bacteria and such can be the most widely spread). This includes the trip home from the store, the time the food is on the table and the time you have it in your bag for lunch at work. In addition, handling by sales people or customers and spraying with contaminated water (for fruits and vegetables) are also important factors. The spraying gives a fresh appearance to the vegetables but also adds organisms. Inclusion of decayed food part during distribution, marketing and storage increases the number of microorganisms in foods.

2.4.4 Food serving factors

During the serving of food, when kitchen tools used for raw food such as meat, poultry, fish or unwashed vegetables come in contact with other food-serving utensils, microorganisms can be transferred. Cooked foods get contaminated if they are placed back on the same plate that previously held food or when left uncovered for a long time, creating opportunities for their contamination by microorganisms present on the body of flies, rodents etc. that can come in contact with the food.

2.5 Food Contamination Mechanism in Some Selected Foods

Fruits and vegetables are at risk of contamination all through the production and distribution network as well as in retail stores, restaurants and in the home. The primary route of most enteric pathogens on fresh produce is animal or human fecal material. According to Elizabeth and Robert, potential direct and indirect contamination of fruits and vegetables can result from contact with the soil, manure, irrigation water, wild and domestic animals, farm, packing house and terminal market workers, contaminated equipment in the field, packing house and distribution system, wash, rinse and flume water, ice, cooling equipment and transportation vehicles or from cross contamination from other food and improper storage

[19]. Shellfish such as mussels, oyster, clams, scallops etc. are filter feeders that operate a bi-valve system, whereby water is taken in through one valve, filtered through their flesh and then discharged through the second valve, resulting in accumulation of bacteria and viruses in the flesh of the shellfish rather than being discharged back into the water. These, in addition to the fact that shell fish are eaten raw or lightly cooked make them a common source of food poisoning. It is essential that shellfish are reared in clean waters and properly treated before use through any of the two main methods –depuration (placing the live shellfish in fresh salty water so that the bacteria in their bodies will filter back into the water) and UV treatment (placing live shellfish in water tanks with ultra violet lights). The flour of root and tuber crops (yam, cassava, cocoyam etc) gets contaminated in the course of milling. Somorin et al. reported that milling machines at Ibadan market harbored significantly high microbial count (2.1x103 cfu cm-1). All the yam flour samples milled in the market had Bacillus megaterium and Staphylococcus saprophyticus. Fusarium oxysporum, Aspergillus niger and Rhizopus nigricans were isolated from both white yam flour and water yam flour. Milling introduced some fungi known to produce mycotoxins into the yam flour. Milling yam chips into flour in the machines available at the markets increased the microbiological contamination of the yam chips by between 101->102 folds due to some unhygienic practices observed during the milling and this has implications for the microbiological quality and safety of the yam flour meal consumed [68]. Milk is a highly nutritious food for pathogenic bacteria. Raw milk (cows') often contains bacteria such as E. coli or even TB or Brucella. Pasteurized milk must be used in food preparation. Pasteurization is a heat process (the milk is heated to a high temperature (72^0C for 15 sec) and then cooled rapidly) used to reduce the numbers of microorganisms in food to a safe level. Most freshly laid eggs are sterile, at least inside, but the shells soon become contaminated by fecal matter from the hen, by the case or nest, by wash water if the eggs are washed, by handling and by the material in which the eggs are packed. Microorganisms that can contaminate eggs are Salmonella, Proteus, Acromonas, Pseudomonas, Alkaligenes, Achromobacter. While Cereals are growing, grains harbor some microorganisms which are retained by the exteriors of harvested grains in addition to contamination from soil, insects and other sources. The families of bacteria that contaminate grains include Pseudomonadacea, Bacillaccae, Micrococcacea and **La**ctobacillaceae. Contamination of grains can still occur during other procedures such as milling, blending and conditioning. Cereal flour is contaminated by spores of bacillus, Aspergilla (toxin producer) and Penicillia. Freshly baked loaf gets contaminated by mold spores from the air during cooling and before wrapping, during slicing by pathogens in the air, on the knives or on the wrapper.

3.0 MICROBIAL CONTAMINANTS AND THEIR COMMONLY ASSOCIATED FOODS

3.1 Introduction

There exist a plethora of microorganisms that may potentially contaminated foods. However, only a small percent of these are pathogenic to humans. According to CAST, more than 40 different pathogens are known to contaminate food and cause human diseases [9]. Several pathogens were recognized only recently as a cause of foodborne illness [70]. For example, until 1982, E. coli 0157:H7 was not recognized as a significant human concern in association with the consumption of contaminated fresh fruits and vegetables [55]**.** Some foodborne pathogens have not yet been scientifically identified [52]. The cause has not yet been identified for more than half of all recognized foodborne disease outbreaks. The Center for Disease Control and prevention has estimated that these elusive unknown pathogens account for 81% of the foodborne illness in the United States [42]. Some foodborne pathogens may be especially virulent. For instance, the incidence of E.coli 0157:47 in raw ground beef is approximately 1%, so the risk the food will be contaminated is relatively low. However, only a few cells of E.coli 0157:47 are necessary to cause illness. The recognized microbiological food contaminants that can cause foodborne illness include [43] bacteria (Clostridium perfringens, Staphylococcus aureus, Clostridium botulinum. Listeria monocytogenes [63], Escherichia coli OI57:H7, Salmonella, Yersinia enterocolitis, Campylobacter species (C fefunii susp fefunii, C. coli, C. lari, C. fetus subsp. fetus and C. upsaliensis), Bacillus cereus, Shigella, Lactococcus cremoris, Vibrio vulnificus, Vibrio cholera), parasites (Entermoeba histolytic, Toxoplasma gondii, Taenia sarginata and Taenia solium, Crystosporidium parvum, Gardia duodenalis, cylospora cayetanensis and Trichinella spiralis), viruses and toxins produced by bacteria and fungi. Most foods, whether raw, cooked or processed to the best of standards can become contaminated and vehicles for disease transmission [59]. In general, raw foods often present a higher risk of cross-contamination and foodborne illness than properly cooked foods. Unlike food spoilage microorganisms that often produce changes in a food's odor and color, pathogens usually do not produce observable changes in food. Therefore, a food that is contaminated with pathogenic microorganisms with the potential to cause disease and death can still look and smell ok. Some selected microbial contaminants, their commonly-associated foods and impact on health are summarized in Table 1.

4. 0 IMPACTS OF MICROBIOLOGICAL CONTAMINATION OF FOOD

4.1 Introduction

The microbiological contamination of food has potential impacts that can be very devastating on food consumers, food businesses and companies. These potential impacts are here presented in three categories- Health impact, Economic impact and others.

4.2 Health impact of microbiological contamination of food

According to Prescott et al. [55], health can be defined as the state of optimal physical, mental and social wellbeing and not merely the absence of disease and infirmity. Food contaminated by harmful bacteria, viruses, parasites or

chemical substances can lead to a wide range of health problems.

4.2.1 Foodborne diseases

Food-containing harmful microorganisms are responsible for more than 200 diseases ranging from diarrhea to cancers [7]. Some other diseases caused by microbial contaminates are cholera, campylobacteriosis, E. coli gastroenteritis, salmonellosis, shigellosis, typhoid and paratyphoid fever, amoebiasis and poliomyelitis (Table 1). Though numerous pathogens cause similar symptoms (such as diarrhea, abdominal cramps and nausea), the illness caused by foodborne pathogens vary with clinical manifestations, severity and duration [55]. Most foodborne illnesses are more severe or prolonged and are limited to brief episodes of diarrhea, nausea or other acute gastrointestinal systems. Several other illnesses can result from the consumption of foods contaminated by microbial pathogens and include fever, vomiting, weakness, chills and aches, headaches, abdominal pain, constipation, sore mouth, blurred vision, muscle paralysis. A small portion of foodborne illnesses are severe or fatal, however complications such as septicemia, localized infection of other organs and spontaneous abortion in pregnant women are the most severe acute illnesses associated with foodborne pathogens that contaminate food. According to Lindsay, an estimated 2.3 percent of all acute foodborne illnesses develop secondary long-term illnesses and complications (called chronic sequellae which can occur in any part of the body including the joints, nervous system, kidneys or heart) that may become chronic health problems [38]. Other complications associated with foodborne pathogens include reactive arthritis, hemolytic uremic syndrome (characterized by kidney failure) and Guillain-barre syndrome (characterized by neuromuscular paralysis). Contamination of foods by Aspergillus and Pencillum species cause health hazard via elicitation of aflatoxins (AFs) induced acute toxicity in animals and humans. The prime target organ for acute toxicity and carcinogenicity in all species is the liver, alongside the lungs [53], [8]. Aflatoxin B1 is carcinogenic to many organs and one of the most potent hepato-carcinogenic in animals and humans. The consumption of aflatoxin-containing corn (6 to16ppm) in 200 Indian villages resulted in over 25 percent fatalities for which the primary cause of death was gastrointestinal hemorrhage [62]. (See Table 1 for other disease symptoms) No individual is exempted from the deleterious impact of food contamination by foodborne pathogen. However, the impact of foodborne pathogens can be especially serious and potentially life threatening for young children, pregnant women and their fetuses, the elderly and people with compromised immune systems. Though younger individuals usually face far higher rates of infection from foodborne pathogens, the very young and older adults are more likely to have severe complications from infection. Evidence has shown that no nation, whether developed or not is free from the health impact of food microbiological contamination. Approximately one in eight Canadians experiences an episode of domestically-acquired foodborne illness each year in Canada [33]. The United States has the safest food supply in the world; that record notwithstanding, some people get sick from eating food [81]. In 1999, an estimated 5,000 deaths, 325,000 hospitalizations and 76 million illnesses were caused by foodborne illnesses within the US [81]. In 2011, the CDC issued new figures for the incidence of foodborne illness, estimating that about 48 million people in the United States suffer from foodborne illnesses each year, resulting in 128,000 hospitalizations and 3,000 deaths [65]. According to Robert Scharff, the decrease doesn't necessarily reflect a decrease in foodborne illness but is primarily due to methodological changes by the Centers for Disease Control and Prevention in how the incidence of foodborne illness is measured [50]. Nevertheless, with this report, one can imagine what the case in developing countries including Nigeria becomes. An unprecedented number of foodborne disease outbreaks have been reported in Nigeria [1], [2].

4.2.2 Death

People really die from foodborne diseases resulting from microbial contamination of food. Contaminated foods are responsible for many more accidental fatalities than some products commonly perceived dangerous including firearms, industrial machinery and explosives [79]. Unsafe food is linked to the death of an estimated 2 million people annually including children [78] and the African Region is without exception.

TABLE 1

SELECTED MICROBIAL CONTAMINANTS, THEIR COMMONLY-ASSOCIATED FOODS AND SYMPTOMS

Selected Microbial Contaminant	Commonly-associated Foods	Health impacts (symptoms)
Clostridium perfringens	Raw meats, poultry, fish, stews, cooked turkey and beef, casseroles, gravy dressings, food that sits for extended periods and dried foods such as spices and vegetables	Perfringens food poisoning (Intense abdominal cramps, watery diarrhea)
Staphylococcus aureus	The red meats, especially ham, poultry, potato, macaroni and tuna salads, custard and cream-filled bakery product, the sandwich sauces.	Staphylococcal food poisoning (Sudden onset of severe nausea and vomiting. Abdominal cramps. Diarrhea and fever may be present.)
Clostridium botulinum	Vegetables, improperly or home-canned or bottled foods, including canned meats, corn beef, canned fish, smoked fish and vegetables, honey, mushroom, improperly processed peppers, asparagus, soup, spinach.	Botulism (Vomiting, diarrhea, blurred vision, double vision, difficulty in swallowing, muscle weakness. Can result in respiratory failure and death)

Listeria monocytogenes	Dairy (soft cheeses and coleslaw), meat products(pate, sausages and gas-packed delicassen goods), cold-smoked and gravid rainbow trout products, sliced cold cuts, soft cheese, butter, ice-cream and coleslawraw vegetables, fermented raw-meat sausages, raw and cooked poultry, raw meats (all types), and raw and smoked fish	Listeriosis (Fever, muscle aches, and nausea or diarrhea. Pregnant women may have mild flu-like illness, and infection can lead to premature delivery or stillbirth. The elderly or immune-compromised patients may develop bacteremia or meningitis.)
Escherichia coli OI57:H7	ground beef, raw milk, chicken, vegetables and fruits, and any food exposed to raw fecal matter is at risk of being contaminated	Hemorrhagic colitis, Severe (often bloody) diarrhea, abdominal pain and vomiting, little or no fever. Can lead to kidney failure.)
Yersinia enterocolitis	Raw vegetables, milk produces, fofu, minced meat, raw pork from where other foods may be cross-contaminated.	(Lymph node Inflammation, Appendicitis-like symptom)
Campylobacter species (C fefunii susp fefunii, C. coli, C. lari, C. fetus subsp. fetus and C. upsaliensis).	Raw meats (beef and pork) water, unpasteurized milk, eggs, chicken, shellfish and mushroom.	Campylobacteriosis (Diarrhea, cramps, fever, and vomiting; diarrhea may be bloody)
Bacillus cereus	Meat and vegetables dishes, cereals, spices, custards, puddings and heat-treated desserts.	Diarrheal: Watery diarrhea and abdominal cramps Emetic: Nausea and Vomiting
Salmonella	Raw meats, eggs, fish shellfish, poultry, Milk and dairy products, fish, shrimp, frog legs, yeast, coconut, sauces, salad dressing, cake mixes, cream-filled desserts and toppings, dried gelatine, peanut butter, cocoa, chocolate, pork. In general, beef is less often contaminated with salmonella than poultry and pork.	Acute gastroenteritis, painful abdominal cramps, diarrhea that may be sometimes bloody, fever (100^0F to 102^0F), vomiting, headache and body aches
Toxoplasma gondii	Raw or undercooked meat, especially pork, or wild game and water	Fever, swollen lymph nodes, especially in the neck, head ache, muscle aches and pains, sore throat: people in high group may develop brain inflammations, seizures, mental issues such as confusion and psychosis; in infected pregnant women, can lead to miscarriage, stillbirth or death soon after birth
Shigella	Salads of potato, chicken, seafood and vegetables, milk and other dairy products and meat products, especially poultry	Shigellosis or Bacillary dysentery (Abdominal cramps, fever, and diarrhea. Stools may contain blood and mucus.)
Entamoeba hystolitica	Tap water, ice cream, ice cubes, shellfish, eggs, salasd, raw or undercooked meat, pealed fruits, sauces	Amoebiasis; loose stool that may be bloody some times, stomach pain, fatigue, excessive gas, rectal pain, amoebic dysentery including high fever, severe abdominal pain and 10 or more episodes of diarrhea daily. Can extent to the liver, causing enlarged liver and unintentional weight loss
Vibrio vulnificus	Undercooked or raw seafood, such as shellfish (especially oysters)	Vomiting, diarrhea, abdominal pain, blood-borne infection. Fever, bleeding within the skin, ulcers requiring surgical removal. Can be fatal to persons with liver disease or weakened immune systems.)
Hepatitis A	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler; shellfish from contaminated waters	Hepatitis (Diarrhea, dark urine, jaundice, and flu-like symptoms, i.e., fever, headache, nausea, and abdominal pain)
Noroviruses	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler; shellfish from contaminated waters	Viral gastroenteritis, acute non- bacterial gastroenteritis, food poisoning or food infection (Nausea, vomiting, abdominal cramping, diarrhea, fever, headache. Diarrhea is more prevalent in adults, vomiting more common in children
Cryptosporidium	Uncooked food or food contaminated by an ill food handler after cooking, contaminated drinking water	Intestinal cryptosporidiosis (Diarrhea (usually watery), stomach cramps, upset stomach, slight fever)
Cyclospora cayetanensis	Various types of fresh produce (imported berries, lettuce, basil)	Various types of fresh produce (imported berries, lettuce, basil)

The specified pathogens cause an estimated 2,718 deaths each year, of which 1,809 are attributable to foodborne transmission. Excluding death due to Listeria, Toxoplasma, and hepatitis A virus, the number of deaths due to pathogens that cause acute gastroenteritis is 1,381, of which 931 (67%) is attributable to foodborne transmission. Bacteria, parasites and viruses respectively account for 72%, 21% and 7% of deaths associated with foodborne transmission. Five pathogens account for over 90% of estimated food-related deaths: Salmonella (31%), Listeria (28%), Toxoplasma

(21%), Norwalk-like viruses (7%), Campylobacter (5%), and E. coli O157:H7 (3%). Some food-related Illness and death result also from unknown pathogens. Infants, young children, pregnant women, the elderly and those with an underlying illness are particularly vulnerable. For example, in 2014, there were more than 100, 000 cases of cholera in 22 countries resulting in over 1700 deaths. So far 2015, cholera outbreaks in 13 countries have led to over 200 deaths out of more than 13,000 cases [78]. Worldwide, diarrheal diseases are second only to respiratory diseases as a cause of adult death and are the leading cause of childhood death. In some parts of the world, they are responsible for more years of potential life lost than all other causes combined [55]. Each year, around 5 million children (more than 13, 600 a day) die from diarrheal diseases in Asia, Africa and South America. In the United States, estimates exceed 10,000 deaths per year from diarrhea and an average of 500 childhood deaths are reported. A Professor of Food Science and Technology, Alfred Ihenkoronye, has said that more than 200,000 persons in Nigeria die annually from food poisoning caused by contaminated foods through improper processing, preservation and service [54]. Research has shown that the elderly are more vulnerable to gastroenteritis-induced death.

4.3 Economic Impact of Food Microbiological Contamination

A single event of a foodborne disease or outbreak resulting from consumption of microbiologically-contaminated food can bring unimaginable economic loses [80] in various forms including unexpected expenditure on hospitalization bills, treatment costs, expenses on recalls, disposal and penalties, legal costs due to foodborne outbreaks, and financial loss due to loss of business. After a notification of foodborne disease outbreak, to protect consumer and general public health, government agencies use recall events to remove potentially harmful products from the market rapidly and efficiently. The cost estimate of food safety incidents to the United States economy is around 5.7 billion spent on notification of customers, recall of food from shelves and paying damages as a result of law suits. Scharff's new analysis, "Economic Burden from Health Losses Due to Foodborne Illness in the United States," offers two economic cost estimates. Scharff arrived at the $77.7 billion figure by including values for medical costs, productivity losses, mortality, and pain and suffering [50]. Estimates include costs attributable to both acute illnesses and resulting conditions, such as hemolytic uremic syndrome and reactive arthritis. Scharff's analysis includes a breakdown of costs associated with each of 31 different foodborne pathogens as well as foodborne illness from unknown causes [50]. In the same US, human illness due to foodborne pathogens (including C. fefunii, C. pertringens, E. coli 0157:H7, L. monocytogenes, salmonella, S. aureus and T. gondii causing yearly, an estimated 3.3 – 12.3million cases of foodborne illness and up to 3900 death) is worth an estimated $6.5 - $ 34.9billion (1995 USS) annually. Besides US, most other countries sometimes have economic loses. Most of these recalls are precautionary and incur huge costs to companies operating expenses. For instance, Fonterra Company in Auckland, New Zealand was reported to have been associated with product microbial contamination which caused foodborne disease outbreak that brought devastating impacts on the company [22], [30], [15]. According to Crutchfield and Roberts (2000), food-borne illness imposes substantial economic costs on society.

4.4 Other Impacts OF Microbiological Contamination Of Food

These include:

i. The supply of unsafe food products
ii. Decrease in sales and exports
iii. Breach of government regulation and standards
iv. Loss of consumers' confidence and loyalty
v. Loss of food company's reputation,
vi. Absenteeism from school, business or work due to ill health,
vii. Discontinuation of food business (closing of business) and
viii. Loss of workforce to death.

5.0 PREVENTION AND CONTROL OF MICROBIOLOGICAL CONTAMINATION OF FOOD

5.1 Introduction

The impact of food contamination can be devastating. Therefore there is always the need to prevent it to mitigate diseases, death, economic loses including financial loss due for loss of business, unexpected expenses on recalls, disposal and penalties, legal costs due to food borne outbreaks, maintain the reputation of food company and consumers' confidence and loyalty, meet government regulations and standards and ensure supply of safe food products. Economic analysis of food safety related costs showed that it is much cheaper for a producer to invest in preventing events of food borne outbreaks than the cost after an event [58]. Microbiological food safety is truly a farm to table issue [5], that is, control of food microbial contamination and the consequent impacts must take place from the primary production to the dining table since the general food produce and animal production practices, general food house peeping, food handling, preparation facilities, conditions of cooking utensils and food contact surfaces, dishwashing and serving practices, food storage system as well as food handlers knowledge and practices affect food safety directly or indirectly. Each pathogen/food contamination represents a combination of many factors. Some maybe best addressed through good agricultural practices to prevent contamination in the first place [19], some may be best addressed by a control step in the processing environment to inactivate any pathogen on food while others may be best addressed by consumer food handling and preparation practices [66]. The different means by which food microbial contamination can be prevented along the food production chain and how to evade food poisoning are here provided. Food safety education for consumers and staff in the food industry is integral to prevention of food contamination and its consequences. The identification of contaminants and the primary infection sources and their importance permits a targeted and efficient prevention and control. As noted by Marika, spreading information and knowledge about the sources and routes of transmission of pathogens into food protects food from contamination and a population from foodborne disease. The exclusion and control of these well estimated risk factors can help to develop safe foods [40].

Essential tools for this purpose are the collection and typing of bacteria from humans, animals and foods, case control studies and monitoring of the occurrence of pathogens in various food groups. Development of methods for measuring antibodies in, for example blood, meat, eggs makes it possible to establish the infection status of herds. According to Wagengar et al., much of the progress has been focused on safer processing of animals and plants after they are harvested with less emphasis on the prevention that can be achieved before harvest or slaughter. Making further progress will need to include a pre-harvest or pre-slaughter factor.

5.2 Prevention of Primary Production Factors (Preharvest and Preslaughter)

Outbreak investigation show that contamination events often start with problems in production that is while growing the plants we harvest or raising food animals. Therefore, early intervention measures during crop development and harvesting through the use of good agricultural practices (GAP) will provide dramatic reductions in pathogen contamination of food and thus enhance substantially, the food safety and shelf life of fresh produce at all subsequent steps in the food-to-fork continuum [18]. Preventing the contamination of raw foods and vegetables pre-harvest is effectively impossible. However, Stier and Odumeru [66] recommended the following for limiting the contamination of crops in the field:

i. Microbiological testing of farm and irrigation water.
ii. Construction of fencing to limit access to feral animals to fields or orchards
iii. Application of manure fertilizers to fields well in advance
iv. Regular clearing of farm equipment

Use of surface rather than spray irrigation, good agricultural practices (GAPs) which include the above recommended measures and other methods is the best approach to preventing produce contamination prior to harvest [57], [66]. In 1998, FDA published the Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables, recommending GAPs that growers, packers, and shippers implement to address the common microbiological hazards that may be associated with their operations [24]. These GAPs are organized in eight categories including Water, Manure and municipal bio solids, worker health and hygiene, sanitary facilities, field sanitation, packing facilities sanitation, transportation and trace back. In addition, FDA worked with the produce industry to develop commodity specific food safety guidelines for sprouts, lettuce and leafy greens, melons, and tomatoes that provided metrics for soil and water amendments as well as adjacent land usage.

5.3 Prevention of pre-slaughter and slaughter contamination

Long term prevention of food contamination and thus foodborne disease depends on actions of many partners in the food production chain, stretching from farm to table [5]. Quality assurance programs at egg farms and safe agricultural practices are integral to prevention of microbiological contamination of meat, poultry and fish during primary production. Development of methods for measuring antibodies in, for example blood, meat juice and egg makes it possible to establish the infection status of herds with respect to bacteria such as salmonella and Y. enterocolitica. Modern industrialized slaughter methods tend to increase infection levels. With the widespread of pathogenic bacteria in meat animals; carcasses may very easily become contaminated. Therefore an effort is necessary in order to improve the slaughter hygiene in critical processes on the slaughter line [5], such as removal of intestines, removal and hocking of chest organs, lymph mode incisions at meat inspection and trimming of head meat. In addition to improved hygiene on the slaughter line, separate slaughtering of infected and non-infected animals may contribute to lower contamination levels in meat for consumption [48]. Some microbes can cause serious illness in humans but rarely cause illness in animals that carry them. The presence of these microbes is not apparent to the rancher and farmer and the animals appear entirely healthy on inspection at slaughter. Therefore addressing these microbes requires a different prevention paradigm based on reducing levels of microbial contamination throughout the areas where animals are raised with attention to fodder, water and biosecurity there [61].

5.4 Prevention of contamination of product at harvest

The contamination of produce at harvest can be prevented by maintaining portable hand washing stations and Lavatories, reinforcing to field workers, the importance of a regular schedule of washing and sanitizing of equipment to ensure that the practice becomes a routine, rather than an afterthought and use of cleanable plastic and fiber glass bulk bins and containers instead of wooden ones difficult to maintain in a clean and sanitized state.

5.5 Prevention and control of food microbial contamination at postharvest

To date, intervention strategies that have been developed cannot completely eliminate microbial growth, therefore the need to prevent contamination. Good Hygienic, Good Manufacturing, Good Distribution and Good Storage practices are key factors in preventing microbiological contamination of food at postharvest [66]. Basic knowledge of proper handling, storage and preparation through consumer education programme minimize microbial contamination and hazards associated with foods.

5.5.1 Preventing food processing/preparation factors: Personal hygiene

It is very easy to transfer contaminants from the hands to foods; therefore proper hygiene is incredibly important. Hand washing with soap and hot water often while working with different types of food and after using the bathroom, changing diapers or handling pets is will minimize contamination. Workers infected with staph should always wear gloves to avoid the spread of the pathogen, given that the organism multiplies without any hint of spoilage. Gloves should be changed often. Any cuts or wounds should be covered with water proof bondages and avoiding the preparation of food for people by the sick including those having a skin infection is also a preventive/control measure. Maintenance routines in food processing are also a factor in food contamination. Hygienic working practices of maintenance personnel should be improved and more hygiene education is needed. Clear hygiene rules targeted to maintenance personnel should be

available for all maintenance personnel. The proper use of protective clothing, washing of hands and tools as well as avoiding foreign bodies left on the production lines should be targeted when the hygienic working practices are developed for maintenance personnel [32], [3]. The results emphasize need for careful use of lubricants during maintenance work and need for regular change of lubricants and cleaning and disinfecting of surfaces between the changes. Improvements in hygienic working practices of maintenance personnel are required with respect to minimizing the occurrence of L. monocytogenes, as well. Though frequent hand washing can prevent food contamination, avoiding cross contamination of different foods as well as washing utensils and work areas can also help. Microbial contamination of food from equipment at the processing plant can be reduced by adequate cleaning and sanitization.

Cutting boards
Washing cutting boards with hot water and soap between use helps minimize contamination. Where possible, separate cutting boards should be ideally used, one for raw foods (meat, poultry, sea food) and the other for fresh produce to prevent cross contamination. Do not prepare salads on cutting boards that have been used for raw meat. In the choice of boards for cutting, either wood or a non-porous surface cutting boards such as plastic, marble or glass or pyro ceramic can be used. However, non-porous surfaces are easier to clean than wood. Both wooden and plastic cutting boards can be sanitized with a solution of 1 tablespoon of unscathed, liquid chlorine bleach per gallon of water by first flooding the surface with the bleach solution allowing it to stand for several minutes and then rinsing with clear water, air drying or part drying with clean paper towel. All plastic and wooden cutting boards become excessively worn or develop hard to clean groves. Once this happens, such cutting boards should be replaced. knives used for cutting raw meat, poultry or seafood must be adequately cleaned before being used to cut other foods such as vegetables (lettuce, tomatoes, carrot) intended for raw consumption .

Water for processing/preparation and Washing of utensils Thorough washing of utensils can prevent cross contamination (that is transfer of harmful microbes from one food via utensil to another). Dish cloths, tea towels, hand towels and aprons should also be washed frequently at high temperature. Water must be properly treated to control the microbial load of the water (US Department of Agriculture) if it is to be used for human consumption and food processing/preparation. Water can be treated via sedimentation which allows solids to settle, filtration (removes smaller remaining particles) and chlorination or UV treatment; used to kill pathogenic bacteria.

Food contact surfaces
Pathogens can spread throughout the kitchen. When preparing food, alongside hand washing, food contact surfaces should be washed often using use hot, soapy water and paper towel or clean cloths often used to wipe up kitchen surfaces or spills. kitchen work surfaces should be regularly cleaned with hot water and detergent and kept free of domestic pest. The most efficient means for limiting the growth of microbes are good production hygiene, the sensible running of the process line and the well-designed use of cleaning and decontamination processes.

5.5.2 Distribution and storage
In addition to GAP and GMP, the spread of pathogens to foods must be prevented and controlled at the distribution, wholesale and retail stages based on self-imposed control according to HACCP. All foods are potential sources of contamination. During distribution and storage, foods (especially fresh produce) get contaminated from contact with transportation vehicles or from cross contamination from other foods or marketers / consumers. Therefore, while distributing and storing food, raw meat, poultry or seafood should be separated from other foods. Because bacteria multiply rapidly on prepared stew, meats and gravy left at room temperature, prompt refrigeration of leftover is very crucial. Correct refrigeration and application of other growth inhibiting principles are also important critical points in the preventive efforts. Raw juices often contain harmful bacteria, thus during refrigeration, raw meat, poultry and seafood should be placed in containers or sealed plastic bags to prevent their juices from dripping onto other foods. Refrigerate or freeze perishable foods within two hours of purchase or preparing them to forestall expected rapid reproduction of bacteria that occurs where foods are not properly cooled. Foods should be refrigerated properly, ensuring that the refrigerator is colder than 40^0F and freezers kept below zero degrees. Perishables such as eggs which often harbor salmonella bacteria should be stored in their original container and kept below 40^0F to decrease contamination.

5.5.3 Serving food
When serving food, clean plate should always be used. Cooked foods should not be placed back on the same plate that previously held food or raw, poultry or seafood. Avoid contamination of your left over by covering the food well and reheat leftovers properly (1650F for at least 15 sec). Defrosting of foods should be done safely by tightly wrapping meat, poultry or fish so that the juices do not drip on other food while defrosting in the refrigerator or alternatively, by putting the frozen food in a plastic bag and immersing it in cold water, changing the water every 30 minutes.

5.6 Measures for preventing food contamination by some selected microbial contaminants

Clostridium perfringens: Food contamination by Clostridium perfringens can be prevented/controlled by keeping heated foods well above C. perfringens maximum growth temperature (50^0C to 52^0C), placing food leftovers in shallow containers in a water bath and ice, not letting food sit out at room temperature for extended period, placing the leftovers in the refrigerator for storage. Always throwing away food that has not been properly heated or cooled is a good measure to prevent infection/intoxication by C. perfringens.

Staphylococcus aureus- Good Hygienic Practices (Monitoring the health, hygiene and work habits of food handlers) is the best prevention method for S. aureus food contamination. Through frequent hand washing and food handlers avoiding touching their faces or infected surfaces while working with food is also an important preventive

measure. Anyone with excessive acne, infected cuts, or symptoms of the common cold should not handle food cleaning and sanitizing equipment and food contact surfaces, rapidly cooling susceptible foods via placing them in containers not more than 3 inches deep or in the refrigerator to attain a temperature of 4^0C within four hours, avoiding the consumption of foods that may be contaminated with S. aureus.

Clostridium botulinum: Care need to be taken when processing and preparing home canned, especially low acid foods such as corn and green beans. Washing vegetables to remove soil and as much C. botulism as possible and not eating home canned low acid vegetables cold important ways of preventing botulism. C. botulism growth can be prevented by freezing food. Low acid foods need to be processed at a temperature of 121^0C to destroy the C. botulism spores

Listeria monocytogenes: The general guideline for reducing the risk of listeriosis includes thoroughly cooking of raw meat and poultry and carefully washing raw vegetables. In addition, people in high risk groups should avoid eating soft cheeses and should also heat all precooked foods and processed meat such as deli meats and hot dogs until they steam.

Escherichia coli OI57:H7: Steps to preventing entry of E. coli into food can be taken by individuals and communities alike. Communities chlorinate water supplies to eliminate bacteria, food handlers need to always wash their hands after using the bathroom and foods need to be cooked thoroughly (71^0C).

Salmonella: Salmonella can be controlled in the market egg production via monitoring of salmonella in breeding and production of flocks. In Danish, control of salmonella via monitoring of the pathogen in finished product lead to a reduction of the occurrence of salmonella in fresh pork to approximately 1% in 1997. The contamination of broilers with salmonella can be reduced via consumer information campaigns, pointing out correct handling and heat treatment as the most important preventive measures. Poultry and livestock producers can reduce the number of salmonellae that occur in animals before and during slaughter.

Entamoeba hystolitica: Good hygienic practices; thorough hand washing after going to the toilet, after changing nappies and before preparation, serving or eating food, infected food handlers should not handle food

Hints on evading food poisoning from Contaminated Foods

Preventing cross contamination is a key factor in preventing foodborne illness and its associated impacts. However, simple precautions can reduce the risk [66].

1. Avoiding the consumption (that is, do not eat) certain foods for example, eating raw meats and fish should be avoided and salads prepared in restaurants where meats and vegetables share a common surface during preparation should be avoided.
2. Bulging cans with rusted lids or cracked leaking jars may contain C. clostridium toxins and so should be thrown out and not even taste-tested.
3. Foods which “sell by” dates are at or beyond those days should be avoided.
4. Intake of raw milk should be avoided; drinking only pasteurized products and washing produce thoroughly helps to protect people from pathogens.
5. Caution should be taken when serving food and any leftover that has been at room temperature for more than two hours or in hot weather for more an hour should be thrown out.
6. Any food you are in doubt it has been prepared, served or stored safely known when to avoid certain foods altogether.
7. Adequate heat treatment, cooking foods properly: The risk of food borne illness from foods contaminated by certain pathogens (especially food-infection-causing (not intoxication-causing pathogens) can be reduced through adequate heat treatment (cooking at temperature between 165 and 212^0F) of foods like meat, poultry, fish and shellfish.

CONCLUSION

The reliable safe supply of food that is free from harmful contaminants is important for the people’s general health and daily life, economic development and social stability and the government and countries’ image. Unfortunately though, many opportunities exist for food to get contaminated along the food production chain (from farm to table), leading to huge devastating impacts, the good news however, is that with certain precautions, food microbiological contamination and the consequential impacts can be mitigated. Microbiological food safety is truly a farm to table issue, that is, control of food microbial contamination and the consequent impacts must take place from the primary production to the dining table and each pathogen/food contamination represents a combination of many factors. Some maybe best addressed through good agricultural practices to prevent contamination in the first place, some may be best addressed by a control step in the processing environment to inactivate any pathogen on food while others may be best addressed by consumer food handling and preparation practices. These precautionary measures come under Good Agricultural Practices, Good Manufacturing Practices, Good Hygienic Practices, Good Transportation Practices, and Good Storage Practices and other guides published to minimize microbial food safety hazards. However, food safety depends on understanding the need to prevent food contamination (through the mirror of food contamination/pathogen impacts) as well as the food contamination pathways or mechanisms, well enough to prevent them. The exclusion and control of the well-estimated risk factors through the above named practices can help to develop safe food all over the world and reduce the socioeconomic burden of foodborne diseases. Surprisingly, recent records show that microbiological contamination/pathogen-contaminated foods still represent important causes of unintentional injury, diseases and death. Besides diseases and death, the consumption of pathogen-contaminated foods has also created economic, social and psychological impacts that were quiet devastating on the consumers, nations and food dealers and companies. The huge impact of microbiological contamination of food recently recorded is suggestive of the following:

1. That microbiological contamination of food is still a serious public health concern.
2. That the next time you bite down on a food, especially that prepared by negligent workers, you consider the risk to your health.
3. The next time you are negligent or hire negligent workers to work with while growing or harvesting plant produce in the field, raising or slaughtering food animals or engaged in any other postharvest/post-slaughter food handling practice, you consider the risk to people's general health and daily life, economic development and social stability and the government and countries' image.
4. Truism in the report that much of the progress in preventing microbial food contamination has been focused on safer processing of animals and plants after they are harvested with less emphasis on the prevention that can be achieved before harvest or slaughter; therefore making further progress will need to include a pre-harvest or pre-slaughter factor.
5. That the technological parameters involved in the farm-to-table food handling including GAPs, GMPs, GHPs, GSPs, GDPs etc. are under harnessed or not sufficient to hinder microbiological contamination.
    - All these highlight a strong need for challenges in food safety to be tackled.
    - The identification of contaminants and the primary infection sources and their importance permits a targeted and efficient prevention and control and should be given priority attention, e.g. while considering proposals for research grants.
    - Food safety education for consumers and staff in the food industry is integral to prevention of food contamination and its consequences and should be promoted.

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