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Public Health Importance of Foodborne Pathogens

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Abstract: Foodborne pathogens cause a considerable public health burden and challenge. They cause illnesses and deaths in all populations, particularly in groups at risk such as infants, children, elderly and immunocompromised persons. Diarrheal diseases, almost all of which are caused by foodborne or waterborne microbial pathogens, are leading causes of illness and death in less developed countries, killing an estimated 1.9 million people annually at the global level. Even in developed countries, it is estimated that up to one third of the population is affected by microbiological foodborne diseases each year. The majority of the pathogens causing this significant disease burden are now considered to be zoonotic. The occurrence of some of these zoonotic pathogens seems to have increased significantly over recent years. The most important source of foodborne disease is raw or improperly cooked food (meat and poultry, raw eggs, unpasteurized milk, shellfish and rice). Food handlers play a major role in ensuring food safety throughout the chain of food production. The most commonly recognized foodborne infections are those caused by bacteria (*Campylobacter spp*., *Salmonella spp*., *E. coli* O157:H7, *L. monocytogenes*); viruses (Hepatitis A virus, Hepatitis E virus, Rotavirus); mycotoxins; marine bio toxins and parasites (*T. solium, T. saginata, Echinococcus spp*., *Trich. spiralis*, *Fasciola, Cryptosporidium parvum*, *Entamoeba histolytica, T gondii*). Symptoms of foodborne diseases greatly depend on the type of pathogen. Numerous organisms cause similar symptoms, especially diarrhea, abdominal cramps and nausea. Pathogens that cause foodborne sporadic diseases and outbreaks are usually detected by specific laboratory tests. The primary goal of foodborne outbreak investigation is to control ongoing and future outbreaks. The general strategy of prevention of foodborne diseases require the application of surveillance and information systems for these diseases and Hazard Analysis and Critical Control Points (HACCP) system in the food production chain from farm to consumers and import/export regulations. Reducing microbiological contamination in meat can be achieved through environmental hygiene, best quality of livestock feed, animal vaccination, mandatory inspection of livestock as well as sanitary standards for slaughter-houses and meat processing plant. Food safety can also be achieved by applying personal hygiene, hygienic handling of food and sanitation of the premises and kitchen utensils. Routine medical and laboratory examination of food handlers should be followed. Planning health education programs for food handlers and consumers are important rules to prevent foodborne diseases.

Key words: Public Health · Foodborne Pathogens · Food Handlers · HACCP

INTRODUCTION

In recent years, rapid globalization of food production and trade has increased the potential likelihood of food contamination. Many outbreaks of foodborne diseases that were once contained within a small community may now take place on global dimensions. It is difficult to estimate the global incidence of foodborne diseases, but it has been reported that in the year 2008, about 2.1 million people died from diarrheal diseases. Many of these cases have been attributed to contamination of food and drinking water. Additionally, diarrhea is a major cause of malnutrition in infants and children [1].

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Developing countries in particular, are worthy affected by foodborne infections due to the presence of a wide range of diseases, including those caused by parasites. Even in industrialized countries, up to 30% of the population has been reported to suffer from foodborne diseases every year. In the USA, around 76 million cases of foodborne diseases, which resulted in 325,000 hospitalizations and 5,000 deaths, are estimated to occur every year [1]. The U.S. Food and Drug Administration[FDA] today issued two proposed rules aimed at helping to ensure that imported food meets the same safety standards as food produced in the United States. These proposals are part of the Food Safety Modifications Acts [FSMA] approach to modernizing the food safety system for the 21st century. FSMA focuses on preventing food safety problems, rather than relying primarily on responding to problems after the fact. The FDA encourages Americans to review and comment on these important proposed rules [2].

Newly recognized microbes emerge as public health problems for several reasons: microbes can easily spread around the world, new microbes can evolve, the environment and ecology are changing, food production practices and consumption habits change and because better laboratory tests can now identify microbes that were previously unrecognized [3].

Foodborne illnesses can inflict an enormous social and economic strain on societies. In 2007, an outbreak of *Campylobacter jejuni*, resulting from consumption of contaminated cheese made from raw unpasteurized milk [4] in USA. In 2009, an outbreak of salmonellosis caused by drug resistant *Salmonella Typhimurium* due to contaminated beef products occurred in the USA [5]. Food contamination creates in the USA, diseases caused by the major pathogens alone are estimated to cost up to US $35 billion annually in medical costs and lost productivity [6].

The importance of foodborne diseases as a public health problem is often overlooked because their true incidence is difficult to be evaluated and the severity of their health and economic impact is often not fully understood. Moreover, there is scarcity of reliable information concerning the prevalence of these infections among the human and animal populations in most countries of the Mediterranean Region. Unawareness is probably responsible for the limited financial resources allocated to food safety in many countries [7] Therefore, the work aimed to throw light on the public health importance of foodborne pathogens.

Foodborne Diseases: Foodborne illness (also foodborne disease and colloquially referred to as food poisoning) [8] is any illness resulting from the consumption of contaminated food, pathogenic bacteria, viruses, or parasites that contaminate food [9], as well as chemical or natural toxins such as poisonous mushrooms. More than 250 different foodborne diseases (FBDs) have been described. Most of these diseases are infections, caused by a variety of bacteria, viruses and parasites.

Raw food of animal origin in many cases is loaded with pathogens. Meat can be contaminated during slaughtering and butchering. Milk may be a vehicle of antibiotic resistant zoonotic pathogens (*S. aureus*, *Strept. agalactiae*, *E. coli*, *K. pneumoniae*, *S. Typhimurium* and *Serratia marescens*) [10] In addition, fish and seafood may be fabricated into smaller cuts by a fish monger at the local level with the possibility of contamination [11].

Fruits and vegetables consumed raw are a particular concern. Washing can decrease but not eliminate contamination, so the consumers can do little to protect themselves. Recently, a number of outbreaks have been traced to fresh fruits and vegetables that were processed under poor sanitary conditions [12]. Using water that is not clean can contaminate many boxes of produce. Fresh manure used to fertilize vegetables can also contaminate them [13].

Fast food is the term given to food that can be prepared and served very quickly. While any meal with low preparation time can be considered to be fast food, typically the term refers to food sold in a restaurant or store with low quality preparation and served to the customer in a packaged form for take-out/take-away [14]. The capital requirements involved in opening up a fast food restaurant are relatively low [15]. Fast food has been implicated to cause serious FBDs and outbreaks [12]. Moreover, transfats which are commonly found in fast food have been shown to cause increase calorie intake, promote weight gain and elevate risk for diabetes [16].

Foodborne Pathogens: The most commonly recognized FBPs include bacteria (e.g. *Campylobacter*, *Salmonella*, *E. coli*, *L. monocytogenes*, *Shigella*, *C. botulinum, C. perfringens, S. aureu, B. cereus*); viruses (Norovirus, Hepatitis A virus, Rotavirus); parasites (*Taenia solium, Taenia saginata*, *Echinococcus*, *Trichinella spiralis, Ascaris lumbricoides*, *Fasciola*, *Cryptosporidium parvum*, *Entamoeba histolytica*, *Toxoplasma gondii*); mycotoxins and marine biotoxins [13].

Bacterial Pathogens: Symptoms for bacterial infections are delayed because the bacteria need time to multiply. They are usually not seen until 12–72 hours or more after eating contaminated food [17].

Diseases Caused by Direct Bacterial Infection: Human get infected with *Campylobacter* **(Campylobacteriosis)** by ingestion of contaminated food (chicken meat). Most strains of *C. jejuni* produce a toxin (cytodistending toxin) that hinders the cells to divide. The sites of tissue injury include the jejunum, the ileum and the colon [18]. Campylobacteriosis produces an inflammatory, sometimes bloody diarrhea, dysentery syndrome, mostly including cramps, fever and pain. *C. jejuni* can lead to secondary Guillain-Barré syndrome [19].

FB salmonellosis (infection with non-typhoidal *Salmonella*) is caused mostly by *S. typhimurium and S. enteritidis*. It is usually contracted from sources such as: improperly cooked meat (poultry, pork and beef), infected eggs and milk, reptiles, pet rodents and tainted fruits and vegetables [20]. Most persons infected with *Salmonella* develop diarrhea, fever, vomiting and abdominal cramps, 12 to 72 hours after infection [21]. FoodNet [22] reported two outbreaks with potential for international spread involving contaminated tahini from Egypt resulting in an outbreak of *S. montevideo* infection.

Enterohemorrhagic *E. coli* like *E. coli* O157:H7 may produce *Shiga*-like toxins [23]. Transmission of pathogenic *E. coli* O157:H7 often occurs via fecal-oral route. A major source of infection is undercooked ground beef; other sources include consumption of unpasteurized milk and juice, lettuce and salami [11]. Disease caused by *E. coli* O157:H7 is known as the "hamburger disease" because of its association with eating hamburgers [24]. *E. coli* O157:H7 infection often causes severe, acute bloody diarrhea (although non-bloody diarrhea is also possible) and abdominal cramps. In some people, particularly children under 5 years of age and the elderly, the infection can cause hemolytic uremic syndrome, in which the red blood cells are destroyed and the kidneys fail [25].

L. monocytogenes has been associated with such foods as raw milk, cheeses, ice cream, raw vegetables, raw and cooked poultry, raw meats (of all types) and raw and smoked fish [26]. The ability of *L. monocytogenes* to grow at temperatures as low as 0°C permits its multiplication in refrigerated foods [27]. *L. monocytogenes* is the causative agent of listeriosis which is the leading cause of death with fatality rates exceeding even *Salmonella* and *C. botulinum* [28]. The manifestations of listeriosis include septicemia, meningitis (or meningo-encephalitis), encephalitis, corneal ulcer pneumonia [29] and intrauterine or cervical infections in pregnant women, which may result in spontaneous abortion (2nd/3rd trimester) or stillbirth [30]. Gastrointestinal symptoms such as nausea, vomiting and diarrhea may precede more serious forms of listeriosis or may be the only symptoms expressed [31].

Vibrio vulnificus causes an infection often incurred after eating seafood, especially oysters; symptoms include vomiting, diarrhea, abdominal pain and a blistering dermatitis [32]. Total mortality in treated patients is around 33% [33].

Ingestion of ***V. parahaemolyticus*** in raw or undercooked seafood, usually oysters, cause acute gastroenteritis. The incubation period of ~24 hours is followed by explosive, watery diarrhea accompanied by nausea, vomiting, abdominal cramps and sometimes fever [34].

M. bovis is a slow-growing, aerobic bacterium and is the causative agent of tuberculosis in cattle. *M. bovis* can also jump the species barrier and causes tuberculosis in humans [35].

Most human tuberculosis cases due to *M. bovis* occur in young individuals and result from drinking or handling contaminated milk [36]. As a result, cervical lymphadenopathy, intestinal lesions, chronic skin tuberculosis (lupus vulgaris) and other non pulmonary forms are particularly common [37].

M. avium **subspecies *paratuberculosis* (MAP)** causes John's disease in cattle and other ruminants and it has long been suspected as a causative agent in Crohn's disease which is chronic inflammatory disease of the gastrointestinal tract in humans; this connection is controversial [38]. Recent studies have shown that Map present in milk can survive pasteurization, which has raised human health concerns due to the widespread nature of Map in modern dairy herds. Map is heat resistant and it is capable of sequestering itself inside white blood cells, which may contribute to its persistence in milk [39].

FB Botulism is caused by eating foods that contain the botulinum neurotoxin (canned vegetable such as green beans, honey, corn syrup) which causes muscle paralysis manifested by the following; double vision, blurred vision, drooping eyelids, slurred speech, difficulty swallowing, dry mouth and muscle weakness. If untreated,

these symptoms may proceed to cause paralysis of the arms, legs, trunk and respiratory muscles. Symptoms generally begin 18 to 36 hours after eating contaminated food, but they can occur as early as 6 hours or as late as 10 days [40]. An outbreak of type E FB botulism has been occurred in Cairo in 1991 and the patients were treated with both heptavalent botulism immune globulin provided to the Egyptian Ministry of Health by the U.S. Army and commercially available trivalent antitoxins. Possible serum sickness during hospitalization was recorded for two of four patients who were receiving commercial antitoxins [41].

Clostridium perfringens intoxication occurs 6 to 24 hours after ingestion of contaminated food. Symptoms typically include abdominal cramping and diarrhea - vomiting and fever are unusual. Very rare, fatal cases of clostridial necrotizing enteritis have been known to involve "Type C" strains of the organism, which produce a potently ulcerative β-toxin [42].

S. aureus produces an enterotoxin that causes food poisoning characterized by short incubation period (1-8 hours); violent nausea, vomiting and diarrhea and rapid convalescence. There is no fever. Sources: cooked food high in protein (e.g. cooked ham), dairy products, salads and bakery products that are held too long at room temperature [43].

Bacillus cereus FBIs occur due to survival of the bacterial endospores when food is improperly cooked. This problem is compounded when food is then improperly refrigerated, allowing the endospores to germinate. Bacterial growth results in production of enterotoxins, ingestion leads to two types of illness; diarrheal type and emetic form "Fried Rice Syndrome" [44].

Mycotoxins and Alimentary Mycotoxicoses: Aflatoxins - originated from *Aspergillus parasiticus* and *Aspergillus flavus*. They are frequently found in tree nuts, peanuts, maize, other oil seeds, including corn and cotton seeds. Aflatoxins cause necrosis, cirrhosis and carcinoma of the liver [45].

Altertoxins - originated from *Alternaria spp*. Some of the toxins can be present in wheat and tomatoes [46]. The toxins can be easily cross-contaminated between grain commodities, suggesting that manufacturing and storage of grain commodities is a critical practice [47].

Fumonisins - Crop corn can be easily contaminated by *Fusarium moniliforme* and its Fumonisin B1 causing oesophageal cancer in humans [46].

Ochratoxin - A, B and C are produced by *Penicillium* and *Aspergillus* species. *Aspergillus ochraceus* is found as a contaminant of beverages such as beer and wine. *Aspergillus carbonarius* is the main species found on vine fruit, which releases its toxin during the juice making process. Ochratoxin A has been labeled as a carcinogen and a nephrotoxin and has been linked to tumors in the human urinary track [48].

Mushrooms — food or poison. Mushrooms have been a very special category of food for a very long time. Although several species of mushrooms are cultivated for human consumption, a significant number of mushroom species are highly toxic [49]. Important toxic mushrooms include:

Amanita phalloides contains 2–3 mg of amatoxins per gram of dry tissue. A single mushroom can kill an adult human. Amatoxins cause inhibition of RNA-polymerase leading to inhibition of protein synthesis and cell death of the intestinal epithelium and liver tissue and liver failure follows [45]. Ingestion of the amatoxin-containing mushroom results in vomiting, nausea, abdominal pain and bloody diarrhea that develop within 6–24 hours. Within 3–4 days, patients develop icterus (yellow skin), hypoglycemia, bleeding, renal failure and sepsis (bacterial infections). The mortality rate in humans is 10–40% [50].

Amanita muscarina is characterized by muscarine, which affects the autonomic nervous system. Within a few minutes to a few hours of consumption of mushrooms containing these toxins, the patient will experience perspiration, salivation and lacrimation syndrome, blurred vision, abdominal cramps, watery diarrhea, constriction of the pupils, hypotension and a slowed pulse [46].

Marine Bio Toxins: In many countries of the world this type of poisoning is a major public health problem, affecting many thousands of people. The most common type is ciguatera, which is associated with consumption of a variety of tropic and subtropical fish, mainly coral fish, feeding on toxin-producing dinoflagellates, or predatory fish containing coral fish [51].

Viral Pathogens: Viral infections make up perhaps one third of cases of food poisoning in developed countries. In the USA, more than 50% of cases are viral and Noroviruses are the most common FBI, causing 57% of outbreaks in 2004 [13]. FB viral infection is usually of intermediate incubation period (1–3 days), causing illnesses which are self-limited in healthy individuals [17].

Shellfish and salad ingredients are the foods most often implicated in **Norovirus** outbreaks [52]. FoodNet [22] reported an outbreak of Norovirus infection associated with imported Japanese oysters in Egypt. The disease is usually self-limiting and characterized by nausea, vomiting, diarrhea and abdominal pain. General lethargy, weakness, muscle aches, headache and low-grade fever may occur [53].

Infection of human **with Hepatitis A virus (HAV)** is an acute infectious disease of the liver and is most commonly transmitted by the fecal-oral route via contaminated food or drinking water [34]. Shellfish cultivated in polluted water is associated with a high risk of infection [54]. Zaher *et al*. [55] demonstrated the occurrence of HAV in meat products (minced meat, beef burger and sausage) as well as in milk and its products (ice-cream and cottage cheese) intended for human consumption in different localities in Egypt. The disease can be prevented by vaccination and HAV vaccine has been proven effective in controlling outbreaks worldwide [56].

Hepatitis E is a "self-limiting" disease but occasionally develops into an acute severe liver disease and is fatal in about 2% of all cases. The disease in pregnant women is more often severe and is associated with a clinical syndrome called "fulminant hepatic failure" with an elevated mortality rate of around 20%. It spreads mainly through fecal contamination of water supplies or food; person-to-person transmission is uncommon [57].

Rotavirus is one of several viruses that cause infections commonly known as stomach flu, despite having no relation to influenza. By the age of five, nearly every child in the world has been infected with rotavirus at least once [58] and adults are rarely affected. Zaher *et al*. [55] demonstrated the occurrence of Rotavirus in meat products (minced meat, beef burger and sausage) as well as in milk and its products (ice-cream and cottage cheese) intended for human consumption in different localities in Egypt. Rotavirus is transmitted by the fecal-oral route. It infects cells that line the small intestine and produces an enterotoxin, which induces gastroenteritis, leading to severe diarrhea and sometimes death through dehydration [59].

Parasitic Pathogens

Helminths: Roundworms, tapeworms and flukes are transmitted to humans via food and water in many parts of the world. Nonhuman hosts play a vital role in the life cycles of many of these parasites. Foods can be made safe by cooking, but not all foods are customarily cooked.

Cestodes (Tapeworms): *Diphyllobothrium latum* can cause diphyllobothriasis in humans through consumption of raw or undercooked fresh water fish containing the plerocercoid larvae or sparganum (infective stage for the definitive host including humans) [60]. Symptoms of diphyllobothriasis are generally mild and can include diarrhea, abdominal pain, vomiting, weight loss, fatigue, constipation and discomfort. In a small number of cases, this leads to severe vitamin B12 deficiency due to the parasite absorbing 80% or more of the host's B12 intake and a megaloblastic anemia indistinguishable from pernicious anemia. The anemia can also lead to subtle demyelinative neurological symptoms (subacute combined degeneration of spinal cord). Infection for many years is ordinarily required to deplete the human body of vitamin B12 to the point that neurological symptoms appear [61].

Though humans usually serve as a definitive host, eating infected meat, fostering adult tapeworms ***Taenia solium*** in the intestine and passing eggs through feces, sometimes a cysticercus (a larva sometimes called a "bladder worm") develops in the human and the human acts like an intermediate host. This happens if eggs get to the stomach, usually as a result of contaminated hands, but also of vomiting. Cysticerci often occur in the central nervous system, which can cause major neurological problems like epilepsy and even death. The condition of having cysticerci in one's body is called cysticercosis [62].

T. saginata, also known as the beef tapeworm is a parasite of both cattle and humans. *T. saginata* occurs where cattle are raised by infected humans maintaining poor hygiene, human feces is improperly disposed off, meat inspection programs are poor and where meat is eaten without proper cooking [62].

The adult stage of ***Echinococcus spp*** lives in dogs, foxes and other canids and intermediate stages normally infect sheep, goats, pigs, horses and cattle. Humans can also serve as an intermediate host if they ingest tapeworm eggs in contaminated water or on raw contaminated vegetables. The larval tapeworms form fluid-filled cysts (called hydatid cysts) in the liver, lungs and other organs of intermediate hosts. Tissue damage may be severe in some cases [63].

Nematodes (Roundworms): *Anisakis* is a genus of parasitic nematodes, which have a life cycle involving fish and marine mammals. They are infective to humans and cause Anisakiasis and fish which have been infected with *Anisakis spp*. (*A. simplex*) can produce an anaphylactic

reaction in people who have become sensitized to immuno-globulin E [64]. Within hours after ingestion of fish meal containg infective larvae, violent abdominal pain, nausea and vomiting may occur. Occasionally the larvae are coughed up. The larvae may burrow into the walls of the bowel and produce severe eosinophilic granulomatous response which may occur 1 to 2 weeks following infection, causing symptoms mimicking Crohn's disease [65].

Trichinosis, also called trichinellosis, or trichiniasis, is a parasitic disease caused by eating raw or undercooked pork and wild game infected with the larvae of a species of roundworm *T. spiralis*. Only three *Trichinella* species are known to cause trichinosis; *T. spiralis*, *T. nativa* and *T. britovi* [66]. The great majority of trichinosis infections have either minor or no symptoms and no complications. Trichinosis initially involves the intestines. Within 1-2 days of contagion, symptoms such as nausea, heartburn, dyspepsia and diarrhea may appear. Later on, as the worms encyst in different parts of the human body, other manifestations of the disease may appear, such as headache, fever, chills, cough, eye swelling, joint pain and muscle pain, petechiae and itching. The most dangerous case is worms entering the central nervous system. They cannot survive there, but they may cause enough damage to produce serious neurological deficits (such as ataxia or respiratory paralysis) and even death [67].

Trematodes: *Fasciola hepatica* (sheep liver fluke) and ***F. gigantica*** (cattle liver fluke) live in the bile ducts of man and herbivorous animals. The eggs must find its way to fresh water to complete its life cycle and develop into the infective stage, encysted metacercariae [68]. Human infection occurs by ingestion of the encysted metacercariae on raw vegetables or in water. Disease symptoms include fever, abdominal pain, weight loss and enlarged liver. Some evidence suggests that heavy or chronic infections of this parasite are associated with liver tumors [69].

Nine species of the trematode ***Paragonimus*** **(Lung Fluke)** reside in many parts of the world, including North America and infect the human lung and occasionally other tissues, including the brain. The most common species is *P. westermani*. Reservoirs are cats and monkeys. In fresh water, eggs develop into microcercous cercariae in snail and then into the infective stage (encysted metcercariae) in fresh water crabs, cray fish and shrimps [68]. Human infection occurs from ingestion of raw or incompletely cooked crabs, cray fish or shrimps. Symptoms of diarrhea, abdominal pain and fever may occur early after infection and progress to coughing and thoracic pain as the worms settle in the lungs. Infections are sometimes initially misdiagnosed as tuberculosis, which can delay effective treatment [70].

Protozoa: *Cryptosporidium* is a protozoan pathogen of the Phylum Apicomplexa that causes a diarrheal illness called cryptosporidiosis. A number of *Cryptosporidium* infects mammals. In humans, the main causes of disease are *C. parvum* and *C. hominis* (previously *C. parvum* genotype 1). *C. canis*, *C. felis*, *C. meleagridis* and *C. muris* can also cause disease in humans [71]. Infection is through contaminated material such as water, uncooked or cross-contaminated food that has been in contact with the feces of an infected individual or animal. The most important zoonotic reservoirs are cattle, sheep and goats [34]. The parasite is transmitted by microbial cysts (oocysts) that, once ingested, excyst in the small intestine and result in an infection of the intestinal epithelial tissue [34]. Cryptosporidiosis can be asymptomatic or cause acute diarrhea or persistent diarrhea that can last for few weeks. Diarrhea is usually watery with mucus. It is very rare to find blood or leukocytes in the diarrhea [72].

E. histolytica is an anaerobic parasitic protozoan predominantly infecting humans and other primates. *E. histolytica* is estimated to infect about 50 million people worldwide [73]. When cysts are swallowed they cause infection by excysting (releasing the trophozoite stage) in the digestive tract. *E. histolytica* infection in human can lead to amoebic dysentery or amoebic liver abscess. Symptoms can include fulminating dysentery, bloody diarrhea, weight loss, fatigue and abdominal pain. The amoeba can actually 'bore' into the intestinal wall, causing lesions and intestinal symptoms and it may reach the blood stream. From there, it can reach different vital organs of the human body, usually the liver and cause liver abscess, which can be fatal if untreated [74].

T. gondii is a species of parasitic protozoa in the genus *Toxoplasma*. The definitive host of *T. gondii* is the cat, but the parasite can be carried by all known mammals. Humans infection (toxoplasmosis) occurs by ingestion of the infecive stage; oocysts (e.g., by eating unwashed vegetables) or tissue cysts in improperly cooked meat [34].

Symptoms of toxoplasmosis are flu-like and self-limiting. However, in case of immunocompromised patients, the most notable manifestation of toxoplasmosis is encephalitis, which can be deadly. If infection with *T. gondii* occurs for the first time during pregnancy, the parasite can cross the placenta, possibly leading to hydrocephalus or microcephaly, intracranial

calcification and chorioretinitis, with the possibility of spontaneous abortion (miscarriage) or intrauterine death [34].

Prion and Creutzfeldt-Jakob Disease: BSE commonly known as mad-cow disease is a fatal, neurodegenerative disease in cattle that causes a spongy degeneration in the brain and spinal cord. BSE has a long incubation period, about 4 years, usually affecting adult cattle at a peak age onset of four to five years, all breeds being equally susceptible [75]. It is believed that the disease may be transmitted to human beings who eat the brain or spinal cord of infected carcasses [76]. In humans, it is known as Creutzfeldt-Jakob disease and by 2009, it had killed 164 people in Britain and 42 elsewhere [77]. A British inquiry into Bovine Spongiform Encephalomyelitis [BSE] concluded that the epidemic was caused by cattle, which are normally herbivores, being fed the remains of other cattle in the form of meat and bone meal, which caused the infectious agent to spread [78]. This infectious agent is distinctive for the high temperatures at which it remains viable; meaning that contaminated beef foodstuffs prepared "well done" may remain infectious [79]. The origin of the disease itself remains unknown. The infectious agent is believed to be a specific type of misfolded protein called a prion. It has been suggested that mad-cow disease is caused by a genetic mutation within a gene called Prion Protein Gene [80].

Detection Methods of Foodborne Pathogens: Detecting FBPs in food can be helpful in investigating outbreaks of FBD, assessing the safety of the product to consumers, assessing the stability or shelf life of the product under normal storage conditions, determining the level of sanitation during product preparation, regulatory compliance and incidence surveys for pathogens [81].

Food samples from the original meal and a stool or vomitus sample will be sent to the Ministry of Health Laboratory for testing to determine if there are any pathogens present. A confirmed FBI only occurs when the pathogens from the original meal and the customer are the same [82].

Detection Methods of Foodborne Bacterial Pathogens [83]:

- Quantitative: Enumerate or estimate the microbial load in the product by direct enumeration; microscopic count, colony forming unit count or indirect determination; most probable number method and enumeration of injured cells by selective media.
- Qualitative: Determine the possible presence of certain FBPs in the food by: pre-enrichment step followed by testing on medium containing selective and/or differential agents, followed by biochemical and serological identification and phage typing.
- Testing for bacterial toxins**:** e.g. *B. cereus* enterotoxin, *C. perfringens* toxin, *E. coli* O157:H7 enterotoxin and aflatoxins by agglutination, radioimmuno-assay and ELISA.
- Molecular methods:
  - DNA probes and hybridization: e.g. Detection of *L. monocytogenes*.
  - Polymerase Chain Reaction: It has been applied for identification of bacterial pathogens. Qualititative and quantitative PCR are increasingly being employed in clinical laboratories [84].

Detection Methods of Foodborne Viral Pathogens [81]:

- Antigen Detection: Viral antigens can be detected by enzyme immunoassays e.g. direct fluorescent antibody, indirect immunofluorescence assay and ELISA.
- Molecular methods:
  - Nucleic Acid hybridization: It is a highly sensitive and specific method for detection of viruses. The specimen is plotted on a nitrocellulose membrane and the viral nucleic acid present in the sample is bound with the specific antibody.
  - PCR: For RNA viruses, reverse transcription is required for PCR. PCR is very susceptible to interference by substances in environmental samples.

Detection Methods of Foodborne Parasitic Pathogens [85]:

- Concentration and Detection methods: There are several techniques to concentrate the stool sample including modified formalin-ethyl acetate concentration method and modified zinc sulfate centrifugal floatation technique. Parasited can be detected by staining e.g. Giemsa staining, acid-fast staining, fluorescent microscopy done by staining with auramine.
- Detecting antigens: This can be done with enzyme immunoassays e.g. direct fluorescent antibody, indirect immunofluorescence assay and ELISA.

- PCR: PCR is another way to diagnose FB parasites.

Regulatory Compliance Testing:

- FDA-Regulation" Testing: Meat and poultry slaughter plants and raw ground products processing facilities are required to test for *E. coli* and *Salmonella* under the provisions of the HACCP program [11].
- FDA Import / Detection Testing: Seafood or other food products; examples include microbial analysis for spoilage microorganisms or pathogens in seafood or cheese **(**aerobic/anaerobic plate counts, coliforms, *E. coli*, yeast & mold counts)[11].
- State Dairy Testing: Pasteurized Milk Ordinance includes tests that relate to the quality of various dairy products by microbial testing and analysis including coliform counts, standard plate counts [11].
- Testing methods [11]:
  - Standard Methods for the Examination of Dairy Products.
  - Standard Methods for the Examination of Seawater and Shellfish.
  - Compendium of Methods for the Microbiological Examination of Food.
  - Bacteriological Analytical Manual of FDA.

Microbiological testing of foods is limited by many factors [11]:

- Spoilage organisms and some indicators may be fairly homogeneously distributed, but pathogens are typically “spotty” in distribution and present at relatively low levels. Because of distribution and sampling problems, sensitivity (false negatives) and specificity (false positives) present continuing challenges.
- The key to detection of bacterial pathogens is usually enrichment which is not an option with viruses and protozoa.
- Bacterial toxins are usually detected by some adaptation of serology. With viruses and protozoa, sample processing and concentration, as well as a sensitive final detection method, are necessary to a satisfactory outcome and problems of false positives with noninfectious contaminants remain.
- Many FBIns are not identified by routine laboratory procedures and require specialized, experimental and/or expensive tests that are not generally available.
- Many ill persons do not seek attention; so many cases of FBI go undiagnosed.

Foodborne Disease Outbreaks [13]: An outbreak of FBD is an episode in which two ore more people present the same disease after ingesting food from the same origin and where the epidemiological evidence or laboratory tests indicate that such food was the vehicle of the said disease.

Outbreak Detection: Outbreaks are detected by various means. Health workers, including medical practitioners, may note a shared exposure among self-reporting cases and report the cluster of cases to public health authorities (e.g. botulism, hemolytic uremic syndrome and listeriosis). Members of the general public institutions such as schools, universities or places of work may detect an outbreak, for instance after a shared meal at a canteen, field day or conference.

Outbreak Investigation: Outbreak investigation is the responsibility of the following professions:

- Health inspectors are interviewing the ill persons and the persons at risk and collect samples for the laboratories;
- The microbiologists in State hospitals or clinics isolate the causative agent from stools, vomitus or suspected food and identify it, thus confirming officially the presence of a FBD outbreak. Then, they immediately report to the health authorities the presence of the pathogenic agent;
- The epidemiologists of health authorities are processing and analyzing the data, formulating epidemiological associations from initial information;
- Then, epidemiologists, veterinarians and physicians work together in order to formulate a ‘hypothesis (Who are considered ill and who healthy), or (Will – eventually – all people who eat contaminated food, be ill or not?)

Methods of Outbreak Investigation

Case-Control study: Cases with FBD are compared with controls regarding their food intake, food preparation practices and other possible risk factors in a given period of exposure. Controls should be representative for the population from which cases were drawn but should not have a FBD in the relevant period of time. The main outcome of a case-control study is an estimate of the relative risk of illness after various exposures estimated by the odds ratio.

Table 1: Examples of Recently Published Results from Outbreak Investigations of Foodborne Diseases

Causative agent	Food implicated	Factors contributig to outbreak	Action taken
E. coli O157:H7[1]	organic bagged spinach	contamination orig-inated from irrigation water contaminated with cattle feces	withdrawal of spinach, support for restriction, public health warning
[2]*Shigella*	Improper cold holding temperatures for raw meat	food-handling and sanitation errors	the restaurant was closed until the deficiencies were corrected
C jejuni[3]	cheese made from raw (unpasteurized) milk	use of unpasteurized milk, insufficient microbiological monitoring of milk and cheese	ñrecommendations on cheese production and education of Public
Salmonella enterica saintpaul[4]	common ingredient in fresh salsa, such as raw tomato	contaminated raw products	Consumers who purchased contaminated salsa discarded or destroyed the product.
drug-resistant *Salmonella Typhimurium*[5]	ground beef products	Errors in refrigeration of the ground meat	Consumers who purchased the contaminated ground beef should discard or destroy the product.
Norovirus[6]	consumption of raw oysters	infected food handler with the virus	exclusion of infected food handler from work
Hepatitis A Virus[7]	food prepared at McDonald's restaurant	Bad food handling and personnel hygiene	instruct McDonald's employees on proper hand-washing techniques
C. *parvum*[8]	mixed salad	Errors in handling of vegetables by food handlers	proper handling of vegetables by food handlers
E. coli O157:H7[9]	cooki dough	Cross-contamination at some stage of the manufacturing process	Food safety recommendations
E. coli O104:H4[10]	Fenugreek sprouts	Errors in handling of vegetables by food handlers	proper handling of vegetables by food handlers
Listeria[11]	Cantaloup	contamination orig-inated from contaminated irrigation water	withdrawal of Cantaloup, support for restriction, public health warning

[1][86]; [2][87]; [3]IFSN, 2007; [4][88]; [5][5]; [6][89]; [7][90]; [8][12]; [9][91]; [10][92]; [11][93].

Cohort study compares attack rates of an illness in those who have eaten certain food items and those who have not. The ratio of these two attack rates is expressed as a relative risk. Cohort studies are used somewhat less often than case-control studies but may be convenient and powerful tool if those at risk are easily listed.

Quick outbreak notification leads to a quick investigation and increases the possibilities of isolation of the causal agent in stool, vomit specimens, even leftovers of food. This can lead the investigator back to the restaurant or supermarket and eventually to the factory or even the farm.

Control Measures: The primary goal of outbreak investigation is to control ongoing and future outbreaks. Ideally, control measures are guided by the results of the ongoing outbreaks investigation.

- Food recall is undertaken by any business that manufactures, wholesales, distributes or retails the suspect food. Before recalling, the public should be informed for the: name of the product, address of the production site, reason of the recall, location where the product may be sold.
- Food seizure is the process by which an appropriate authority removes a food product from the market if the business does not comply with recall.
- Closing food premises: If on site inspection reveals a situation that poses a continuing health risk to consumers, it may be advisable to close the premises until the problem has been solved.
- Control of transmission by public advice, exclusion of infected and advice on personal hygiene.

Prevention and Control of Foodborne Diseases: The general strategy of prevention is to understand the mechanisms by which contamination and disease transmission can occur well enough to interrupt them [94].

Control of Pathogens in Food of animal origin [95]: Reducing microbiological contamination in meat is a priority for the prevention of FBDs and can be achieved through the following:

- General attention to livestock management including well established environmental hygiene and transport as well as sanitary standards for slaughterhouses and meat processing plant.
- Monitoring of the quality of livestock feed (avoidance of meat and-bone meal in ruminant feeds) from all sources is essential. Feed additives and feed medication must be stored in areas in such a way that contamination with other chemicals, rodents and insects is avoided.

- Mandatory inspection of livestock (cattle, sheep, goats, equines, swine, chickens) before slaughter and mandatory postmortem inspection of every carcass.
- Educational programs must aim at raising the level of awareness of producers, meat handlers and consumers with regards to the safe handling of meat.
- Livestock producers and food-animal veterinarians must be aware of changing requirements for farm-animal FS as hazard analysis and other risk-reduction activities.
- Pasteurization may not destroy all pathogenic microorganisms present in milk but it reduces the number of harmful microorganisms to a level at which they do not constitute a significant health hazard.
- Proper cleaning, processing, storage, handling, marketing and cooking of highly perishable aquaculture products will minimize potential safety hazards.

Control of Mycotoxins and Marine Biotoxins: The problem of contamination of feed and foodstuffs with mycotoxins is best tackled by a systematic examination of the whole production, processing and distribution chain in order to discover the points at which contamination is likely to occur. In this way appropriate preventive and control measures can be taken. In the USA, the acceptable level of total aflatoxins in foods is less than 20µg/kg, except for aflatoxin M1 in milk, which should be less than 0.5 µg/kg [96]. Control efforts are mainly directed towards trying to predict and remove relevant algal blooms and to pre-harvest examination of shellfish for toxins in order to prevent contaminated products from reaching the consumer [11].

Reducing Veterinary Drugs: In order to limit the development of antibiotic resistance, the availability of drugs is limited to veterinary professionals. The levels of residues of veterinary drugs in foods of animal origin are monitored annually and the results made public [11].

Hazard Analysis and Critical Control Points (HACCP) [7]: The HACCP is a systematic approach to the identification, assessment and control of hazards. It is very simple because it only identifies potential FS problems and determines how and where they can be controlled and prevented. Therefore, HACCP provides a FBD prevention system and a cost-effective approach to FS.

Hygiene in Mass Catering: Important Rules to Prevent Foodborne Diseases [13]:

- Personal Hygiene
- Hygienic Handling of Food
- hygienic measures in premises and Kitchen Utensils:

Ensuring That Food Handlers Are Fit to Work with Food [97]: Taking under consideration that the information taken by a medical examination or a microbiological examination of specimens is rather expensive and valid only for the time at which is carried out, we can't advise it as a regular practice in food-processing plants. However it is obvious that a tool of investigation and method of prevention is needed in order to ensure FS and decrease the incidence of FBDs. Specifically, in gastrointestinal diseases such as, non-typhoid salmonellae, physical examinations or microbiological tests won't reveal the carriers. In these cases only questioning may reveal a history of disease.

Routine Medical or Laboratory Examination of Food Handling Personnel: In some countries, the legislation requires some examinations to be one or more of the following:

- Brief physical examination by a physician, trained nurse, or a manager 2- Taking the medical history by a physician. (It can be performed also by a short questionnaire).
- Examination of feces for parasites; salmonellae, shigellae and other microorganisms.

Treatment of Foodborne Disease Cases: There are many different kinds of FBDs and they may require different treatments, depending on the symptoms they cause. Illnesses that are primarily diarrhea or vomiting can lead to dehydration. Replacing the lost fluids and electrolytes and keeping up with fluid intake are important. If diarrhea continues for more than one day, prepare and drink oral rehydration salts solution (ORS) and continue to eat normally [13]. Seek medical help if diarrhea lasts for more than 3 days and/or there are very frequent watery bowel movements, blood in the stools, repeated vomiting or fever. When there is no medical help available, a course (5 days) of trimethoprim/sulfamethoxazole (for adults: 160 mg of trimethoprim and 800 mg of sulfamethoxazole, twice a day for 5 days; for children: 5 mg of trimethoprim and 25 mg of sulfamethoxazole per Kg of body weight, twice a

day for 5 days); may be taken. Antidiarrheal preparations of bismuth subsalicylate (e.g., Pepto-Bismol) can reduce the duration and severity of simple diarrhea [13].

Current Situation in the Eastern Mediterranean Region [98]: In recent years, an increasing number of countries have moved to improve, update and strengthen their systems and infrastructure for FS and have adopted an approach based on risk management. The United Arab Emirates and Jordan have developed modern food control systems based on risk management to monitor and control the safety of domestically produced and imported food. Oman and Tunisia have developed a national strategy for food control. Lebanon, Egypt, Pakistan, Sudan, Syrian Arab Republic and Morocco have drafted new food legislation. Saudi Arabia, Jordan and the Islamic Republic of Iran have established a food and drug authority. Members of the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) have developed a common food import policy which allows for shared inspection policy and standards. The inspection systems for domestic and imported food of the United Arab Emirates make use of hand-held computers and customized software, which enhances access to information of on high-risk foods, accelerates clearing processes and improves performance of FS. Some countries have well-functioning FB surveillance systems and reporting mechanisms, such as Jordan, Kuwait, Oman and Saudi Arabia. Given the strong reliance of the Region on food imports, ensuring the safety and quality of imported food is a recognized concern throughout the Region Many countries in the Region have embarked on unifying FS activities from farm to fork, such as Jordan, Saudi Arabia and Bahrain. They have established or are establishing food and drug authorities which will cover food laws and regulations, food control management, FBD surveillance and investigation systems, inspection services, recall and tracking systems, food monitoring laboratories and information and education activities for the consumers themselves.

CONCLUSION AND RECOMMENDATIONS

In light of the research work presented, we can say that each day millions of people become ill and thousands die from a preventable FBD. Food contamination creates in the world diseases that are estimated to cost up to billions dollars annually in medical costs and lost productivity. Preventing FBD is a multifaceted process, without simple and universal solutions. For most FBPs, no vaccines are available. Consumer education about basic principles of FS, an important component of prevention, by itself is insufficient. Food reaches the consumer through long chains of industrial production, in which many opportunities for contamination exist. We need to enhance our public health FS infrastructure by adding new surveillance and subtyping strategies and strengthening the ability of public health practitioners to investigate and respond quickly. We need to encourage the prudent use of antibiotics in animal and human medicine to limit antimicrobial resistance. We need to continue basic and applied research into the microbes that cause FBD and into the mechanisms by which they contaminate our foods and cause sporadic cases and outbreaks, through:

- Collaboration of the regulatory agencies and industry to make food safely and keep it safe throughout the industrial chain of production.
- Application of the general strategy known as HACCP to replace the strategy of final product inspection in the developing countries.
- Application of special personal protective equipments to prevent the high risk activities such as slaughtering and preparing ready to eat foods.
- Controlling of *C. jejuni* infections in poultry.
- Applying public health measures for controlling FBPs in animals reservoirs including apparently healthy animals and the safety of what food animals eat and drink
- Translating FB outbreaks new research questions into research agendas.
- Research to improve the diagnosis, clinical management and treatment of severe FBIs and to improve our understanding of the pathogenesis of new and emerging pathogens.
- Health edhcation of food handlers about personal hygiene, hygienic handling of food and hygienic measures concerning premises and kitchen utensils.
- Legislation certificate of food handlers which should include medical and laboratory examinations of them.
- Notificaton of the local authorities about diseases affecting food industry workers (Hepatitis A, diarrhea, vomiting and fever) during their work.
- Consumer education about basic principles of FS, an important component of prevention.

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