Foodborne Diseases: Causative Agents, Prevalence and Control

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ABSTRACT: In this globalized scenario foodborne diseases are spreading more rapidly than ever like other infectious disease. Main reason behind emerging foodborne diseases are microbiological agents but some chemical agents and weather conditions may also contribute to the prevailing issue of food illnesses. Best way to control foodborne diseases is to ensure the hygiene conditions during food preparation and consumption e.g., washing hands before preparing and eating food. Cleaning raw food, proper cooking and pasteurization can also help in prevention of foodborne diseases. A number of international corporations are working to overcome the global issue of food illnesses.

Keywords: Foodborne diseases, microbiological agents, chemical agents, prevalence and control

INTRODUCTION

Since late 20th century with the globalization of political economy there is an increase in the interdependence among the countries due to rapid mobility of people, values, and financial operations across national borders. In this globalized environment where more than 1 million people cross the international borders per day, the risk of transmission of infectious diseases cross the border is also elevated. The diseases spread more effectively and at faster rate as the world becomes highly interconnected. Economic globalization demands firm governmental laws and policies. The emergence of new infectious diseases along with the reemergence of the old ones depicts a crucial concern regarding transnational policy. International cooperation is required to solve these mega problems because of their huge
and interlinked nature (Käferstein et al., 1997).

Consumption of unhealthy food is a constant threat to public health along with the socio-economic development across the world. WHO is trying to provide maximum information about health related issues present throughout the globe. Collaborative efforts are required to assess worldwide scenario of foodborne diseases (Kuchenmüller et al., 2009).

In the past, the public health authorities in developed countries had been faced with a rising number of food safety issues. Epidemiologic surveillance of foodborne diseases is of utmost importance for devising food safety programs and strategies for prevention and control in these countries. Various surveillance programs such as population-based surveillance; outbreak and sentinel surveillances; laboratory-confirmed cases; disease notifications; case-control studies of sporadic diseases; hospital discharges and death registrations help in a proper assessment of a disease outbreak in a particular region at a specific time (Käferstein et al., 1997).

Drinking contaminated water and eating unsafe food can lead to a greater chance of having a water or foodborne disease. Microbial agents causing foodborne diseases can be influenced by weather. The U.S. federal and state laws and regulatory programs protect most of the population from waterborne diseases; but due to environmental changes and the deficiencies in infrastructure, watershed protection and storm drainage systems may probably increase the contamination risks. Understanding the transport processes and the fate of rainfall and snowmelt associated microbial pollutants is a key to predict the risks due to a change in the variability of weather. In order to escalate the early-warning and prevention capabilities the use of modern technologies is inevitable (Rose et al., 2001).

**SOURCES OF FOODBORNE DISEASES**

It has been previously evinced that the epidemiology of foodborne diseases is rapidly altering and pathogens like *Escherichia coli* O157:H7 and the epidemic strain of *Salmonella Typhimurium* DT 104 (resistant to at least five antimicrobial drugs), have become crucial public health concerns. The major factors responsible for emergence of infectious and foodborne diseases are the changes in demographic features, human behavior, microbial adaptation, industry and technology, disruption of public health infrastructure and the inclination towards the global economy (Altekruse et al., 1997).

It has been reported that the healthy edible animals may serve as reservoirs to the worldwide spreading pathogens like *Salmonella*, *Escherichia coli* O157:H7, *Campylobacter*, and *Yersinia enterocolitica*, from which these microbes can spread through various kinds of foods. Due to such pathogens, millions of cases of sporadic diseases and chronic illnesses have been recorded moreover large and challenging outbreaks over many states and nations (Tauxe, 1997).

According to the study by Archer and Kvenberg, annually 68.7-275 million cases of diarrheal disease episodes occur from all causes, exhibiting 0.29-1.1 cases per person.
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per year on average in US. The estimated total number of cases of foodborne illness and subsequent person-to-person transmission was 24-81 million or more per year (Archer and Kvenberg, 1985).

In industrialized countries, foodborne zoonoses pose a serious health impact. For the risk analysis in the food chain, new European food safety regulations had been issued. It is necessary to assess the human vulnerability to biological hazards transmitted by food and foodborne zoonoses. To control the foodborne illness, for meat, the inspection at the slaughter house is of prime importance to protect consumers. (Fosse et al., 2008)

CAUSATIVE AGENTS OF FOODBORNE DISEASES

Major Foodborne pathogens include Salmonella (Salmonellosis), Campylobacter, Staphylococcus aureus, Hepatitis A Virus (HAV), Escherichia coli (E. coli), Listeria cytogenes (Listeriosis), Norovirus, Toxoplasma and Clostridium perfringens (US Food and Drug, 2019).

Salmonella is a group of bacteria that causes the foodborne illness called Salmonellosis. It is the most common cause of foodborne-related hospitalizations and deaths. Salmonellosis can spread easily due to unhygienic cooking methods. Salmonellosis is usually caused by consuming raw or undercooked eggs, meat, seafood and poultry, unpasteurized milk and contaminated dairy products as well as raw fruits and vegetables contaminated by food handlers. It can also be transmitted through contact with infected animals or infected people. It is severe in people with weak immune system. It can be prevented by adopting good hygiene habits and appropriate cooking methods (Wolfram et al., 2017).

Campylobacter causes the infection Campylobacteriosis. It is a common cause of diarrhea. Eating raw or undercooked poultry and meat can result in the infection. Campylobacteriosis occurs more frequently in summer than in winter. It mostly affects infants and young children. Proper heating of food is necessary to kill the Campylobacter bacteria (Wolfram et al., 2017).

Staphylococcus aureus (staph) is one of the normal flora of the human body. It usually does not cause infection until it is transferred to the food products. Nausea, stomach cramps, vomiting or diarrhea are the common symptoms of Staphylococcus infection. These bacteria can be transmitted from person to person by direct or indirect contact. They spread easily through wounds, abrasions, by touching the contaminated surfaces, using unpasteurized dairy products and contaminated food. Certain group of people including the people suffering from chronic conditions such as diabetes, cancer, vascular disease, eczema and lung disease and have a weakened immune system are more likely to develop staphylococcus infection than others. Practicing proper hygiene, keeping the infected areas covered and clean and taking food safety measures can prevent the spread of this infection (Wolfram et al., 2017).

Escherichia coli O157:H7 is one of the Shiga toxin producing types of E. coli (STEC). It is a major foodborne pathogen. It can cause severe disease in humans. It results due to the consumption of undercooked or unpasteurized food products. It can be fatal for young
children, elderly and immunocompromised patients. It can be prevented by proper cooking, pasteurization and cleaning of the food products and taking care of hygiene (Wolfram et al., 2017).

*Listeria monocytogenes* causes listeriosis. It is a severe infection usually affecting elderly people, pregnant women, young children and immunocompromised patients. These bacteria can grow at refrigerator temperatures so they can be found in refrigerated, ready-to-eat foods, unpasteurized milk, dairy products, raw sprouts and raw and undercooked meat, poultry and seafood. Keeping the refrigerator clean and its temperature at or below 40 °F, eating freshly cooked or prepared food, reheating of the precooked food, avoiding unpasteurized food products, washing the fruits and vegetables before use can help in preventing the spread of listeriosis (Wolfram et al., 2017).

Norovirus is the most common cause of gastroenteritis. Its common symptoms include stomach pain, nausea, vomiting and diarrhea. Norovirus infection spreads easily via direct or indirect contact with an infected person or the contaminated surfaces and contaminated food. Anyone can get infected with norovirus but it can be serious and even fatal in young children, older adults and people with other health problems. Prevention includes hand washing and disinfection of contaminated surfaces. There is no vaccine or specific medicine available for norovirus. Treatment mainly aims at the prevention of dehydration (Wolfram et al., 2017).

*Toxoplasma gondii* is a parasite that causes toxoplasmosis. It may result in serious complications in pregnant women, infants, and people with weakened immune systems. Most of the infected people never develop symptoms but in some people it may cause flu-like symptoms with swollen lymph glands or muscle aches and pain that last for months. Severe toxoplasmosis affects the eyes, causing reduced or blurred vision, pain, redness or tearing, damage to the brain and other organs. Eating undercooked, contaminated meat, unwashed contaminated fruits and vegetables, drinking contaminated water, using knives, cutting boards or other utensils that have had contact with raw, contaminated meat; coming into contact with infected cat feces and receiving an infected organ transplant or transfused blood can result in infection. It can also be transmitted to infants if a mother has become infected before or during pregnancy (congenital toxoplasmosis). Cooking food to safe temperatures, washing fruits and vegetables before eating, avoiding unpasteurized dairy products, washing kitchen utensils thoroughly, wearing gloves when gardening or cleaning cat’s litter box can help in preventing toxoplasmosis (Wolfram et al., 2017).

*Clostridium perfringens* is one of the leading causes of bacterial foodborne illness in the United States. It is reported to cause one million illnesses per year (Grass et al., 2013). It is commonly found in the intestinal contents of man and animals, decaying vegetation and soil. It can grow in inadequately cooked or refrigerated food and produce toxins that can cause diarrhea and abdominal discomfort (Bryan, 1969).

*Clostridium perfringens* has been classified into five toxinotypes (A to E) based upon their ability to produce four major toxins (alpha, beta, epsilon, and iota) (Yoo et al.,
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1997). Only type A (primarily) and type C (occasionally) are associated with human illnesses whereas the other types produce diseases in domestic animals. (Shandera et al., 1983).

*Clostridium perfringens* type C & D isolates have been reported to cause fatal diseases in domestic animals which in turn produce a huge economic impact. Due to this, the domestic animals are usually vaccinated with crude type C/D toxoid or bacterin/toxoid vaccines (Fisher et al., 2006; Sayeed et al., 2005).

*C. perfringens* type A isolates carrying a chromosomal enterotoxin gene (*cpe*) have been known to predominantly cause the food poisoning in Europe and US (Li et al., 2007).

During the late 19th century, 20% of the reported food borne disease outbreaks due to *C. perfringens* occurred in Finland. The investigation was performed by doing PCR of *cpe* gene of *C. perfringens* isolates. Later they were also subtyped by pulsed-field gel electrophoresis (PFGE) (Lukinmaa et al., 2002).

A study was reported regarding the estimation of population level of *Clostridium perfringens* in food. The titer of α-toxin present could correspond to the previous growth of *C. perfringens* in food regardless of the viability of the organisms at the time of examination. This is valuable for screening the foods that are responsible for the food poisoning. (Harmon and Kautter, 1976).

The countries with the high rate of meat and poultry consumption have *Clostridium perfringens* as a leading cause of bacterial foodborne illness (Lin and Labbe, 2003).

It has also been found that the countries which have banned the usage of growth-promoting antibiotics in poultry feed have increased incidence of necrotic enteritis due to *C. perfringens* in poultry. The α-toxin producing type A and to some extent both α and β-toxin producing type C of *C. perfringens* cause the necrotic enteritis and the subclinical form of *C. perfringens* infection in poultry (Immerseel et al., 2004).

In 1945, *Clostridium perfringens* in cooked chicken has been identified as a root cause of four outbreaks of foodborne illnesses. The contaminated meat and the food prepared from it are usually responsible for the illness. Spores with high heat resistance are known to impose higher risk of causing a disease (Hatheway et al., 1980).

In Pakistan, clinico-pathological studies of enterotoxaemia in Chinkara deer (*Gazella bennetti*) have been reported. According to the observation the mortality rate was found to be significantly higher in young animals. There were 66.67% and 33.33% of peracute and acute deaths respectively. The pathological, clinical and histological signs of enterotoxaemia are similar to the ones caused by *C. perfringens* type D isolate (Hussain et al., 2014).

According to the study in 2016, foal diarrhea has been reported as the most common cause of mortality in working equines in Lahore and Sahiwal districts of Punjab, Pakistan. Out of 65.77% of diarrheic cases, 72.6% were caused due to bacteria. E.
coli (48.77%) was found to be the most prevalent bacteria than Clostridium perfringens (18.56%) and Salmonella (17.9%) (Haq et al., 2018).

In humans, the infection due to Clostridium perfringens can be prevented by cooking the food at safe internal temperature, refrigeration of leftover food to a temperature of 40 °F or lower within 2 hr of preparation and reheating at minimum 165 °F or higher before serving. Keeping the food warm at minimum 140 °F or cool maximum at 40 °F can help in preventing the growth of C. perfringens spores. In animals, the prevention involves proper management and vaccination (CDC, 2015; Fisher et al., 2006; Sayeed et al., 2005).

WORLDWIDE STATISTICS OF FOODBORNE DISEASES

In 1990s, the regional Food Inspection Services in The Netherlands presented a report regarding foodborne illnesses. According to the investigation, out of 7,567 ill people, 2,621 were suffering from foodborne illnesses. The food from the restaurants and snack bars served as a source of foodborne diseases in more than half of the incidents. Based on the laboratory investigations, in only 8.3% of the incidents, the probable etiological agents including Bacillus cereus, Clostridium perfringens, Staphylococcus aureus, Escherichia coli, Salmonella spp. and chemical toxins were identified (Simone et al., 1997).

In another study, based on face-to-face interviews by using structured questionnaires, knowledge, attitudes, and behavior of Italian food handlers regarding foodborne diseases and food safety issues were evaluated. Depending upon the response of the food handlers, only 48.7% of 411 participants knew about the major foodborne pathogens like Salmonella spp., Staphylococcus aureus, Vibrio cholerae or other Vibrio spp., Clostridium botulinum, and hepatitis A virus. The awareness was considerably greater among those with a higher education level. The results have accentuated the necessity of educational programs for improving knowledge, management and control of foodborne diseases (Angelillo et al., 2000).

STATUS OF FOODBORNE DISEASES IN ASIA

In the late 1990s, a dramatic increase in the foodborne outbreak in Taiwan was observed due to Vibrio parahaemolyticus. It constitutes about 61-71% of the total outbreaks occurred during the period of 1996-1999. Vibrio parahaemolyticus has an extraordinarily high infection frequency and the ability to spread worldwide. Therefore, it is necessary to have intensive global monitoring of this organism (Chiou et al., 2000).

A study was conducted about the foodborne diseases outbreak due to adulteration, chemical and microbial agents during the period of 1980-2009 in India. It has been observed that there were total 37 outbreaks in 3,485 of people. These outbreaks were mostly of bacterial foodborne diseases however the high number of mortality was due to the presence of chemical contaminants in foods (Vemula et al., 2012).
In another study, carried out in Dhaka (Bangladesh), the microbiological quality of local food products sold by the street food vendors in schools was assessed. One food sample from each of 110 street food vendors belonging to 80 schools from 19 school zones of Dhaka city was collected for laboratory analysis. The food vendors were also interviewed according to the predesigned questionnaire. After the laboratory analysis the food samples were classified based on microbial criteria recommended by the International Commission on Microbiological Specification for Foods (ICMSF). The laboratory analysis of food samples revealed that 44% of food items were “unsatisfactory”. It was also observed that the food samples collected from the vendors having an educational status higher than a primary level have less probability of being classified as “unsatisfactory” than the ones collected from the vendors having a daily wage of more than $ 3. The poor microbiological quality of such food items indicated a serious health threat to the school children in Dhaka (Momin et al., 2013).

In 2016, in order to implement the prevention and control measures in Deptsang village (Bhutan), an investigation was conducted to identify the source and cause of foodborne disease outbreak. For the laboratory analysis and antibiogram, stool samples from the patients were collected. A community wide inspection of environment and hygienic conditions was also performed. Out of 55 villagers who consumed the carcass meat, 33 suffered from food poisoning. The results showed that there was a statistically significant association between the consumption of carcass meat and the resulting acute gastroenteritis. By the laboratory analysis, multi-drug resistant *Aeromonas hydrophila*, susceptible to chloramphenicol only, was identified to be the major etiological agent of the gastroenteritis. A risk ratio between the people who ate carcass meat and those who didn’t was calculated to be 2.1. These observations could help in devising the strategies to prevent such incidences in the future (Tsheten et al., 2016).

During 1992-2001, a project was designed to investigate the foodborne disease outbreaks in thirteen provinces of China, covered by National Foodborne Disease Surveillance System. Total 5770 outbreaks and 162,995 infected people were reported. The outbreaks due to microbial agents constituted 38.5% whereas the chemical agents caused 37.5% of the outbreaks with known causes. *Vibrio parahaemolyticus* accounted for the largest number of outbreaks. It is the need of the hour to improve the foodborne disease surveillance system (Liu et al., 2004).

In 2008, an outbreak of hepatic veno-occlusive disease (VOD) due to Pyrrolizidine alakloids (PAs) was reported in Western Afghanistan. Historically it’s been called “Gulran Disease” because of its consistent outbreak in the Gulran district of Afghanistan. The investigation was carried out by using a case-control design. The consumption of bread was found to be associated with the disease. The laboratory test results showed the presence of PA in the collected plant extracts and wheat flour samples at the toxic level. The PA level in milk and whey was found to be far lower than the wheat flour. The PA content was zero in water sample. A wheat flour used to make bread contaminated with PA was believed to be the probable source of the...
aforementioned outbreak. The consumption of various kinds of foods including meat and fruits, the assessment of PA content of the food samples and implementation of routine testing in the previously affected areas may help in preventing the spread of this disease (Kakar et al., 2010).

In late 1990s, a study was conducted on the outbreak of botulism in the northern province of Iran. The infected patients were interviewed and their families were also investigated for the detection of infection. The clinical and food samples were collected and tested for the pathogens. *Clostridium botulinum* type A and its toxin were identified in clinical specimens and the cheese. It was the 1st documented outbreak of botulism because of *Clostridium botulinum* type A in cheese in Iran (Pourshafie et al., 1998).

**STATUS OF FOODBORNE DISEASES IN PAKISTAN**

In developing countries like Pakistan, foodborne illness is one of the major concerns. It is caused by the consumption of food, contaminated with microbes or exposed to the chemicals. The most widely spread foodborne outbreak is the one due to microbes. Because of the lack of knowledge and unhygienic conditions, the exposure of food during its preparation, handling and storage to the toxic chemicals can also result in the outbreak of foodborne diseases (Javed, 2016).

For the study of risk analysis of occurrence of foodborne infections due to the foodservice facilities at the bus and railway stations in Pakistan, the food-vending operations were carefully observed and evaluated to identify the sources and the modes of contamination, the temperatures of food items were measured during and after cooking and reheating to determine the microbial survival, growth and destruction, the food samples like rice, pulses, chick peas, potato mixtures, okra, meat stews and gound meat etc were collected and microbiologically tested to identify the etiological agent. *Clostridium perfringens* was isolated in abundance from the samples collected during display and after cooking. In addition to this the colony counts of aerobic bacteria were also high in the collected samples that were held for many hours. However, the food was observed to be safe which was kept at high temperatures or reheated periodically (Bryan et al., 1992a).

In another study, the possibility of occurrence of foodborne illnesses due to contamination of chat (a regionally popular dish of Pakistan) at the vending stands was evaluated. It was found to be contaminated with Staphylococci, *Bacillus cereus*, coliform and aerobic mesophilic bacteria. Consumption of such foods may lead to serious diseases. Proper cooking, minimum handling of food, reduced holding and display time can help in controlling the spread of foodborne diseases. (Bryan et al., 1992b).

During the hazard analysis of milk based products in three confectionery manufacturing establishments in a big city in Pakistan, the khoa (dried evaporated milk solids) and the cheese based confectioneries were evaluated. Khoa was found to be contaminated with Staphylococci and enterotoxins on arrival and even after cooking at high temperatures due to occurrence of recontamination during handling. The confectioneries, prepared from khoa and
renin-processed cheese, were found to be contaminated with Salmonellae. These products might have got contaminated during cooling or handling after cooking. Such contaminated milk based products pose a high risk of spreading foodborne diseases (Teufel et al., 1992).

A study was also carried out to investigate the prevalence of deadly foodborne pathogens in miscellaneous types of locally consumed food items in Pakistan. In addition to the culture techniques, the DNA based approaches were also used for the detection and identification of foodborne pathogens. Out of 800 collected food samples including raw milk, meat, chicken, vegetable and salads, 48.37% were found to be contaminated with opportunistic bacteria like Campylobacter jejuni, Salmonella spp., E. coli (O157:H7) and Listeria monocytogenes. Some food samples were discovered to be co-infected with at least two pathogens. These results have proven the alarming and unhygienic conditions prevalent in local food markets (Samad et al., 2018).

TREATMENT AND CONTROL OF FOODBORNE DISEASES

Food safety and disease control are the matters of global interest. Assuming that the infectious diseases were under control, the governments had shifted their focus from the public health problems related to communicable diseases and long-lasting effects of chemicals in the food supply, after World War II. However, the food safety priorities regarding chemical and microbial hazards have gradually changed in the last four decades. Emergence of new pathogens, the occurrence of much discussed water and foodborne disease outbreaks and the apparent incapability of the public health authorities to control the diseases has raised much attention of the world towards these matters (Todd, 1997).

Data about the foodborne disease outbreaks, based on notifications, laboratory analysis, and sentinel or population-based studies can provide a detail insight into foodborne disease problems, their trends over the time and their economic impacts (Käferstein et al., 1997).

Generally, there is always a high risk of foodborne disease outbreak due to the lack of availability of effective vaccines against foodborne pathogens and the insufficiency of the food safety education among the food producers, handlers and consumers. The consumers can be protected from the serious diseases by enhancing the food safety measures throughout the chain of production, from farm-to-table. Many foodborne illnesses can be controlled by preventing the food contamination before its usage by the consumer (Tauxe, 2001).

In a study regarding the control of foodborne microorganisms, the antimicrobial activity of Moringa oleifera leaf’s and seed’s chloroform and ethanol extracts against some selected foodborne pathogens was investigated. According to the results of antibacterial assay, the M. oleifera leaf ethanol extract displayed broad spectrum activity against the test organisms. Pathogens like E. coli, P. aeruginosa, S. aureus and Enterobacter aerogenes were found to be susceptible to M. oleifera leaf ethanol extract. M. oleifera seed chloroform extract was proved to be only active against E. coli and
Salmonella typhimurium. According to antifungal activity assay, at a concentration of 1mg/ml of M. oleifera seed chloroform extract, the Mucor and Rhizopus species had shown 100% growth inhibition. (Bukar et al., 2010).

In the prevention of foodborne diseases significant progress has been achieved. For instance, in the early 20th century, the typhoid fever epidemics were quite common which are now almost eradicated in the US. During the preantibiotic era, the disinfection of drinking water, sewage treatment, milk pasteurization, and shellfish bed sanitation helped in the eradication of the disease. Likewise, cholera, bovine tuberculosis, and trichinosis have also been restrained in the US. However, the emergence of new foodborne pathogens has imposed new challenges. It is necessary to enhance the preventive measures to control the foodborne disease outbreaks (Tauxe, 1997).

In 1996, for the surveillance of foodborne diseases, a national molecular subtyping network “PulseNet USA” began working in the United States. It has proven itself as a “critical early warning system” for the outbreaks of foodborne diseases, especially for the ones which are geographically dispersed. Since 2000, the PulseNet network has also been established in Canada, Europe, the Asia Pacific region, and Latin America. These independent networks collaborate under the aegis of PulseNet International. Its objectives are to allow public health officials and laboratorians to share molecular epidemiologic information in real-time, to enhance the surveillance of foodborne disease outbreaks at a global level and to issue an early warning regarding the water and foodborne disease outbreaks, emerging pathogens and acts of bioterrorism (Swaminathan et al., 2006).

**CONCLUSION**

Foodborne diseases present a worldwide problem. They impose both economic as well as health loses throughout the world. The only way to control foodborne disease is the implication of proper hygiene methods in cooking and eating food.

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