FOOD SAFETY CONCERNS AND FOOD-BORNE PATHOGENS, *SALMONELLA*, *ESCHERICHIA COLI* AND *CAMPYLOBACTER*

ALI AKBAR AND ANIL KUMAR ANAL*

Food Engineering and Bioprocess Technology, School of Environment, Resources and Development, Asian Institute of Technology Klong Luang, Pathumthani 12120 Thailand.
E-mail address: anilkumar@ait.asia

Abstract

Meat can be contaminated with different types of foodborne pathogenic bacteria, which can cause a verity of health complication in human particularly enteric illness. Ingestion of mishandled, undercooked or cooked meat can lead to disease. A number of foodborne pathogens are responsible for the cause of infection related to meat. *Salmonellosis* and infection related to *Escherichia coli* are the most frequent and major part of foodborne infections worldwide. Prevalence of salmonella and Escherichia coli is relatively high as a meet borne infection. There is a number of emerging pathogens and emerging food vehicle which are becoming threat to food safety. Globalization of food products, expansion of food business and change in food eating habits bringing new food safety hazards threats. The growing rate of antimicrobial drug resistance in food borne pathogen is also becoming a major problem for food safety. Which not only creating health problem but also exerting economic burden on national and international economies. Food safety systems like microbiological risk assessment (MRA) and HACCP has been designed for the control of food borne pathogens and for achievement of food safety and to reduce zoonosis. Food preservation with the help of hurdle technology is getting attention due to its promising safety as well as stability of the products.

Introduction

Microorganism presence in food is natural and is hard to avoid its entry, but by cooking or heating to some extend it can be destroy. Presences of microorganisms hazardous to human health are considering health threats (Narang, 2004). In case of un-cooked, processed ready to eat and partially cooked food can have pathogenic microorganism which are serious health risk. The perishable food like Meat, poultry and dairy products are the main source of food borne pathogens particularly *Salmonella*, *Campylobacter*, *Listeria*, and *Escherichia coli* O157:H7 (Bhunia and Lathrop, 2003). Any disease or toxic nature caused by or thought to be caused by the consumption of water or foods are termed as food born disease or illness (Adams and Moss, 2008). While the ingestion, growth and toxin production of food borne pathogen in the host body are food born infection and the toxic products or cell components of pathogen cause intoxication. More than 200 recognized microbial, chemical and physical agents can cause disease in case of ingestion (Acheson, 1999).

Foodborne disease, usually either infection or toxic in nature, are caused by agents that enter the body through the ingestion of contaminated food, some time also called food poisoning. It is one of the widespread and great public health problems of the modern world (WHO, 2000). The majority of foodborne illness in the UK is probably due to *Campylobacter, Salmonella, Escherichia coli O157, Listeria monocytogenes* and *Clostridium perfringens* (CDSC, 2002). It is not only the cause of mortality and morbidity worldwide, but also a significant cause of reducing economic productivity. Each year throughout the world, million of people particularly infants and children suffer and die from food borne infections. While the role of food handler, processer and producer should not be underestimate (WHO. 2000; CDSC, 2002). It has been estimated that the risk of becoming ill as a result of microbial contamination of food was 100,000 times greater than the risk from pesticide contamination (Adams and Moss, 2008). Gastroenteritis diseases are mostly related to food such as meat, poultry and its products which show symptoms after 8 hours incubation in the human body. A small error during food processing and packaging, particularly in meat and poultry products can lead to a major epidemic. It has been identifies that cattle is a source for *E. coli* O157, and is a common vehicle for transmitting the bacteria from animals to humans (Perry *et al*., 2007). Food control is necessary for consumer as well as industry to gain the confidence of consumer and strengthen it market. It was the prim concerned before 1940 to avoid and control microbiological contamination in food. But now food safety covers all areas of chemical composition, hygienic aspects, nutritional adequacy and authenticity. Processing of food play an important role to extend the shelf life and preservation of food (Anklama and Battagliab, 2001). Leclerc *et al*., (2002) stated that, a 10 year backdated study shows that pork products were involved in outbreaks as often as milk products in the ratio of almost six ratio five (Leclerc *et al*., 2002). Foodborne diseases are equally important to governments, food industries and common publics (Adak *et al*., 2002). Raw milk and food products cooked and un-cooked were most commonly contaminated with food borne pathogens, some of them show multidrug resistance (Farzana *et al*., 2009)

Food Safety: In the new era of production and trade, government and public are the two major stockholders of food safety, and the responsibility also goes to food producer, supplier and other relevant authorities deal with food and food industries. Food safety covers all aspect of food contamination from chemical to biological contamination. It has been estimated that about 1.8 million people died from diarrheal diseases as a result of contaminated food in 2005 (WHO, 2007). For the majority of food borne pathogen there is no vaccine available and particularly the new emerging pathogens are more hazardous than the old (Robert, 1997). It is getting high interest from public health authorities, to reduce the chance of any terrorist attach of intentional contamination of food supply (Waterman and Ibrahim, 2009). The data regarding potential microbiological risk of food are very limited (Marthim, 1999). Less than 10% of the foodborne diseases incidences are reporting declared by the world Health Organization (Domiguez *et al*., 2009). There are four major groups including temperature misuse, raw materials, inadequate handling, and environmental factors responsible for foodborne outbreaks (Panisello *et al*., 2000). In England and Wales almost 51% of the outbreaks linked to commercial catering business, while 11% to private home and 10% residential setting responsible for over half 59% of the hospitalization and over half 57% of the death (Hughes *et al*., 2007). Data from WHO showed that 224,000 person suffered from *Salmonella* contaminated ice cream in USA in year 1996, While in china 300,000 individual infected with Hepatitis-A after using contaminated calms in year 1998 (WHO, 2007).

Different tools are in practice to manage the microbiological hazards such as Microbiological Risk Assessment (MRA) and HACCP systems to achieve microbiological food safety from farm to folk (Perni *et al.*, 2009; WHO 2010). To promote food safety, WHO is developing polices regarding food safety to ensure protection during the entire food chain. Food safety department of WHO working to promote food safety systems, good manufacturing practices and it implementation in food industries, to reduce the risk of contamination and to control the food borne outbreaks (WHO, 2007). WHO and FAO assembled an expert consultation on risk assessments of microbiological hazards in FAO headquarter on 30 April to 4 may 2001. Risk assessment for microbiological hazards has acknowledged the precedent area of work for Codex Alimentarius Commission (WHO / FAO. 2001).

Human intestine is the ecological niche for a verity of microorganism, and can carry both normal flora and pathogenic bacteria. The estimated microbial load of human intestine is in trillions with about 40,000 species. The majority of the intestinal pathogens are zoonotic (Taylor, 2009). Infected food worker have been widely connected to the food borne outbreaks of *Salmonella* in several investigations. Transmission can occur due to the improper hand washing or precaution of infected food handlers (Hedican *et al*., 2009). It is studied that most of zoonotic pathogens are associated to at least one main reservoir and a few route of transmission, which is usually food animals. Anthropological and environmental recontamination of processed food at final stage or after final preparation are also considered and analyzed in some recent studies. Current study showed that zoonotic and some non-zoonotic enteropathogens from human reservoir to other individual are important (Greig and Ravel, 2009). The people with immunocompromised status are more vulnerable to food borne illness. Particularly AIDs and transplant patients are more likely to be in great care and vigilance. *Escherichia coli* are now considering the most common pathogen causing diarrhea in HIV infected patients. Some other food borne bacteria like *Salmonella* cause Salmonellosis in immunocompromised patients, while *Listeria, Toxoplasma* and *Cryptosporidium* are also considered as a major food borne pathogens in for Immunocompromised people (Pandit *et al*., 2002; Canadian Pediatric Society, 2008). Kids are also broadly affected by the acute diarrheal illness worldwide caused by food borne pathogens. An estimated value of childhood death due to diarrheal illness is 2.5 million per year throughout the world (Marcus, 2008).

Foodborne disease and Public health: Food bone infections are the major cause of hospitalization and death throughout the word (Van *et al*., 2007). In the United States of America each year about 76 million of food borne related illness, and almost 5000 deaths are estimated, causing by known and unknown pathogens. The infections by known pathogen like *Salmonella*, *Listeria* and *Toxoplasma* are 14 million lead to 60,000 hospitalization and 1,800 deaths each year. While a huge number of cases are related to unknown pathogens. There are more than 200 known diseases which can transmit through food to cause food borne illness including Virus, bacteria, Parasite, Toxins and prions. The sign and symptoms of these diseases range from mild intestinal problem to Life-threatening chronic and acute disease like hepatitis and kidney failure. New trends in the food supply, production and trades are also leading to the emergence and spreading of food borne pathogens and emergence of new and more dangerous serotype and species (Paul *et al*., 1999).

Epidemiology of food borne diseases is rapidly changing and foods previously thought safe are now studied as unsafe and contaminated. The emergence of new pathogens and known food borne pathogens are now associated with new food vehicles and way of transmission is changing. A number of microorganisms considering high risk pathogens today were not recognized as a causative agent of food borne infections. For example, *Campylobacter jejuni*, *E.coli* O157:H7, *Listeria monocytogenes* and *Cyclospora cayetanesis*. Several emerging food borne diseases may cause chronic clinical complication or even disability some time. *Listeria*

monocytogenes can cause miscarriages in pregnant women and animals or result in meningitis in patients with chronic diseases. Toxoplasmosis can lead to congenital complications and *E. coli* O157:H7 with association of traveler and kid diarrhea can also lead to hemolytic uremic syndrome, or kidney failure (Altekruse *et al*., 1997; Robert 1997; Paul *et al*., 1999). The large number of food borne disease is thought to be caused by unknown pathogens. Even in United States of America, according to (Paul *et al*., 1999) the proportion of the unknown pathogen causing food borne infection is more than 70% (Paul *et al*., 1999). 68% outbreaks were not identified from 1993 to 2002. The outbreak is considered as of known etiology when at least one clinical sample is laboratory conformed from the affected peoples (Domiguez *et al*., 2009).

The cause of the emergence of new pathogen or reappearance of established ones are weakly understood, but are often related to the ecological change and disturbance by the human beings. Furthermore the changing way of food production, improvement, traveling and trades have affected the transmission routs of food borne pathogen, and it will continue to affect in an unfavorable way the epidemiology of food borne infection (Tassios and Kerr, 2009). It has been declare by WHO that about 1.8 million kids died in 1998 in developing countries (excluding china) caused by biological agents or microorganisms originating from food and water. Every third person in the industrialized countries may be victim of food borne infections (WHO, 2010).

Food borne infections are equally important in developed and developing countries. Almost 2.5 million childhood deaths occur annually due to acute food borne diarrhea. Though diarrhea is less common in developed countries as compared to developing countries, but equally considerable. About 4% of hospitalization and 2% of outdoor patients among kids are due to diarrhea (Marcus, 2008). The reported cases of Salmonellosis in Australia have averaged around 6000 annually from 1992 to 1998. While the under report cases of food borne Salmonellosis are estimated between 240,000 to 650,000 annually (Sumner *et al*., 2004). Diarrheal diseases are the main public health problem in Thailand and each year approx more than 120,000 are reported food poisoning (Minami *et al*., 2010).

Meat as major vehicle of foodborne diseases: In the majority of food borne infection it is not possible to identify the food vehicle. Poultry meat are considering the most common reported food borne pathogens vehicle followed by red meat and deserts. Poultry, red meat, deserts and egg are known as a major vehicle for *Salmonella* outbreaks, it can also transfer the other pathogen like *E. coli* and *Campylobacter* species (Hughes *et al*., 2007). The red meat and poultry are more likely to become contaminated with pathogen during handling due to its perishable nature (Canadian Paediatric Society, 2008).

Meat is very much perishable food and can become contaminated or spoiled and hazardous due to the microbial growth and activities, if not stored, processed and distributed correctly and carefully. All meat products particularly fresh meat has a small number of microorganisms when expose to favorable growth condition can make the meat unusable for human consumption. The non pathogenic environmental species can make the meat spoil and attractive for the growth of pathogenic bacteria. Present of pathogenic bacteria like *Salmonella*, *E.coli* O157:H7, *Listeria*, etc or their toxic products make the meat undesirable for human consumption and its ingestion lead to cause gastro intestinal diseases. Different food safety systems and practices are available to implement in food industry particularly meat industry to reduce the risk of contamination and spread of pathogen (McDonald and Sun, 1999).

Emerging trends and epidemiology: The world culture is rapidly changing and new trends of food processing, transportation and trade are getting place, while the nature and habits of people are also rapidly changing. Changes in habit and technology have some major effects on food safety. Food borne diseases are increasing widely, possibly due to the increasing complexity of food supply chain and changing life style of the people throughout the worlds. All such changes are responsible for changing the drug sensitivity pattern and emergence of new pathogens previously considered of less importance (Robert, 1997; Ravel *et al*., 2009).

Pathogens are rapidly spreading worldwide but the reasons are still remain unknown. For example *Yesinia enterocolitica* spread in pigs throughout the world in 1970s and *Salmonella enteritidis* expend globally in 1980s, while *Salmonella typhimurium* definitive type (DT) 104 is now becoming food safety threat for North America and Europe. With the emergence of new pathogens, new foods vehicles of transmitting pathogens are also becoming a problem. Meat, unpasteurized dairy products and seafood are usually known as food pathogens transmitting vehicles, but now the new food vehicles previously though as safe are becoming prominent. Internal contents of egg were consider safe or free of pathogen are now largely associated with *Salmonella enteritidis* transmission. *Cyclospora* epidemic in United States in 1996 were associated with imported raspberries. Norwalk virus usually associated to human has been isolated from oysters harvested from pristine water. On account to consumer demand and the worldwide food business, companies used to use a number of ingredients from different countries in a single dish (Robert, 1997).

Outbreak of 2007 in America made familiar the expert with new food vehicles. Botulism was linked with a pasteurized carrot juice, while a huge number of outbreaks of infection linked fresh bagged baby spinach contaminated with *E.coli* O157:H7. While a number of *Salmonella* out breaks were linked with quite new

source like tomato, peanuts butters, and vegetarian salty snack and turkey pot pies (Robert, 2008). The common microorganism of sea water and commensal of shellfish *V. vulnificus* are now linked to food borne infections associated to eating raw oysters or being exposed to sea water (Robert, 1997).

Technological and industrial growth: The movement toward large geographical distribution and high business from one point to the different part of the world can lead to the spread and transmission of infectious agent and wide food borne outbreaks. When the product is contaminated at low level may cause sporadic infection instead of spreading large outbreaks (Altekruse *et al*., 1997). Changes in food consumption affect the microbial food safety and bring new and unknown food borne hazards. The habit of eating fresh fruit and vegetables are increased 50% from 1970 to 1994. Fresh products are more susceptible to food borne pathogens as compared to treated and frozen products. Use of Fast food and ready to eat food are now increasing rapidly which was rare to see 50years ago (Altekruse *et al.*, 1997).

Ready to eat food are widely used and available in different varieties with different recipes. The ingredients like rice, noodles, vegetables and meat are cook together and then stored after packing. "Steam meal" recently developed is now a new form of ready to eat food with its freshness as a result of raw ingredient like vegetable meat, packed and store at low temperature. Consumer used to cook the meal before consumption, but due to the presence of raw materials in mix form the contamination may even remain after cooking or heating which can lead to any outbreak or infection (Perni *et al*., 2009). Poor hygienic practices are also associated with food borne diseases. Food can get contaminated with the unhygienic practices and instruments like cutting board, machines and all other related materials used in food processing (WHO, 2004).

Emerging food borne pathogens: The epidemiology of pathogens are rapidly changing and new pathogens as a food borne pathogen are emerging and a well-known pathogen may be linked to food for the first time (Robert, 2008). Non-typhoid strains of *Salmonella* have rapidly increased after World War II. During the last decade's new infectious agent are defined or newly associated with food borne transmission. *Vibrio vulnificus*, *Escherichi*a *coli* O157:H7 and *Cyclospora cayetanensis* are some examples of newly described pathogens. In 1982 *E. coli* O157:H7 were first conformed as a food borne pathogen present in hamburgers of the fast food chain in which caused outbreak. *Cyclospora*, known previously as Cyanobacteria like organism, emerge as a food borne pathogen in 1992 in an outbreak (Robert, 1997). *Listeria monocytogenes* previously thought to be the cause of meningitis and other chronic infection in immunocompromised people are now identified as one of the prominent cause of food borne infection. Similarly *Campylobacter* were previously known as an opportunistic pathogen is now the main food related infection in developed countries. *Yersinia enterocolitica* infection is common diarrhea causing pathogen in Northern Europe thought to be frequently associated to uncooked pig meat. These infections are mostly related to asymptomatic animals or human with no active infection (Robert, 1997).

New serotype of *Salmonella* has identified in Europe and North America with a slight difference in the flagellar antigens. This is very common in America as food borne pathogen (Robert, 2008). The enteric microbiome is a good atmosphere for the horizontal transfer of gene that is why; the enteric diseases caused by well-known pathogen are not the only challenge, but the bacteria changing their genome, recent evidence show that the *E. coli* change itself according to the intestinal condition. This is a main process through which, the normal flora some time becomes as an active pathogen against it own hosts. Common example of such pathogens are vancomycin resistant *Enterococcus faecalis* and *E.coli* which is now present as enteropathogenic, enterohaemorrhagic, enterotoxigenic, enteroaggregative, enteroadherent and enteroinvasive **(**Taylor, 2009). The causative agent of lethal encephalitis Nipah virus was recently isolated from fresh sugar palm sap in Bangladesh (Luby *et al*., 2006). Charges disease has been relating to drinking fresh sugar cane juice acai fruit juice in Brazil. *Toxoplasma cruzi* is also identified as a food borne parasite or pathogens (Robert, 2008).

Avian influenza like bird flu is a major threat to human health and it is an emerging pathogen which not only spread among chicken but also in human, and is responsible for a number human death in several outbreaks. Avian Influenza outbreak in the year 2003 resulted 30 million chickens scrap, while infect 87 human being leaded to one death (Kijlstra *et al*., 2009).

Economic loss due to food borne infections: Food borne diseases are not only a major public health problem but it also have some economic impacts on individual and nations or countries, food borne disease outbreaks from bacteria like *Escherichia coli*, *Campylobacter* and *Salmonella* can cause a big pressure on the health care system directly by getting more health related expenditure, average place coverage in the hospitals and as well as reduce the economic productivity of the countries (WHO, 2004). The data regarding economic cost of food contamination and food borne infections are limited. The estimated costs of 3.3 to 12 million food borne infection cases caused by seven pathogens in United States of America were worth of 6.5 to 35 billion US dollars. In year 1996 the cost of five food borne outbreaks in Wales and England were estimated at GB£ 300-700 million. In Australia the cost of food poisoning was estimated at AU$ 2.6 billion per annum (WHO, 2010).

The estimated economic cost of Campylobacteriosis due to poultry meat is about 14.4 million US dollar in Belgium only (Morn *et al.*, 2009). In Thailand, the reported rejection of contaminated poultry products with *Escherichia coli* and *Enterococcus* of one of the country largest poultry manufacturer are estimated 100,000 US dollar in 2006 (Keeratipibul *et al*., 2009).

Escherichia coli: It is difficult to monitor and detect every food born pathogen in food product for the safety of any food products. So preference goes to such bacteria which can able to show the food safety status of the concern food. Such bacteria are called indicator bacteria. *Escherichia coli* is one of the indicator bacteria for fecal contamination, indicate the presence of coliform and other enteric bacteria which may contaminate the food products. It presence in food show the probability of other pathogen like *E. coli* O157:H7, *Salmonella*, *Enterococcus*, and many more (keeratipibul *et al*., 2009). *Escherichia coli* the commonly known normal flora of intestinal tract of human and animals, its group are not consider normally pathogen of concern, but one particular group called Shiga toxin producing *Escherichia coli* (STEC) has been identified the most potential pathogen and can cause bloody diarrhea and even death in some cases. This group is now common throughout the world particularly O157: H7 are the most common strain which is responsible for the majority of infection cause d by this group of *E.coli* (Leclerc *et al*., 2002).

E. coli is now known as the main food borne pathogen and Enteropathogenic, enteroinvasive, and enterotoxigenic types can be a cause of food borne diarrhea. It is thought that *E.coli* O157:H7 get enterohaemorrhagic gene from *Shigella*, including shiga like verocytotoxins gene, which make this new strain more pathogenic, first studied in 1982 and now common all the over the world. The route of transmission of this bacteria is oral fecal and its infectious dose is about 500 bacterial cell. A large number of hamburgers were recalled by a meat processing plant during august 1997 due to the contamination of *E. coil* O157:H7. The pathogenicity of this strain is much higher in young. In the 1982 in a Sevier diarrheal outbreak due to the consumption of fast food, *E. coli* O157:H7 was first time identifies and a pathogen (Altekruse *et al*., 1997). After an extensive research the infection related to *E. coli* O157: H7 is now recognized, but still the management of this pathogen is a big problem among human and animals used for food (Robert, 1997). The pathogen is now known as a causative agent of bloody and non-bloody diarrhea and about 20,000 cases and 250 deaths occur each year in America due to this pathogen. The out breaks of this organism re also reported in Canada, Japan, Africa, the United Kingdom and many more area of the world. *E. coli* is now also identified as the major cause of hemolytic uremic syndrome, which is the cause of kidney failure in kids in United States of America (Altekruse, 1997).

There is zero tolerance for *E. coli* O157:H7 in ready to eat (RTE) food and it monitoring is of special concern in such food (keeratipibul *et al*., 2009). It was decided by the Council of state and Territorial Epidemiologists that Shiga toxin-producing *E. coli* will be called *Enterohaemorrhagic Escherichia coli* or EHEC (Centers for Disease Control and Prevention. 2003; Atlanta Centers for Disease Control and Prevention, 2005). This pathogen is known as a major threat due to its changing behaviors and ability to acquire external gene to become more pathogenic. This is how this previously thought normal flora or opportunistic pathogenic bacteria are now categorized in different strain according to its pathogenicity. For-example enteropathogenic, enterohaemorrhagic, enterotoxigenic, enteroaggregative, enteroadherent and enteroinvasive (Taylor, 2009).
Escherichia coli are largely consider to the food borne pathogen, health cattle and other animals are reservoir of this pathogen from where it spread to human so also known as food borne zoonoses , its infection always rely on host health condition (Robert, 1997). Cattle are mostly associated with *E. coli* and consider as an important reservoir of human pathogenic *E. coli* strains. In Canada the beef are the important vehicle for this pathogen. It is estimated that 41% of food borne infections are associated with ground beef (Greig and Ravel, 2009).

The organism can spread commonly with the help of beef, poultry meat, water, swimming in untreated water and contact with cattle (Marcus, 2008). It is recently studied that the chicken sold in the markets may be risky for young women and can cause urinary tract infection. According to McGill University researcher (2010) *E. coli* present in these foods can cause common urinary tract Infections. The meat may become contaminated with this bacterium during it processing or sale on the out lets. Some infection caused by *E. coli* show some resistance to common Antibiotics, which may be result of the use of antibiotic in animal feed to prevent them from diseases (McGill University, 2010). Several epidemiological repots identified that pathogenic *Escherichia coli*, (*E. coli* O157:H7) is the great cause of outbreaks associated to contaminated meat. Examination of raw meat is mostly focused on the presence of *Enterohemorrhagic Escherichia coli* (EHEC) group (Lee *et al*., 2009). From its first outbreaks in 1982 it has been consider that product of animal origin like meat and it products (beef, deer, goat, pork, poultry, fermented sausages, salami, etc), mayonnaise, raw milk, raw milk cheese but also vegetable products (salad, radish, fresh potatoes, cider, etc.) are largely associated with these out breaks. To avoid any undesirable microorganism invasion in food and its product good hygiene practice is necessary to adapt during the process (Leclerc *et al*., 2002).

Salmonella: *Salmonella* is gram negative (G-ve) bacterial pathogen with a wide range of hosts belongs to Enterobacteriaceae family (Raghunathan *et al*., 2009). *Salmonella* is composed on two species *Salmonella enterica* which is further divided into 6 subspecies and *Salmonella bongori*. The body antigenic classification is based on somatic "O", flagellar "H", and capsular "K" antigens. *Salmonella typhi* and paratyphoid are serotype, largely responsible to cause enteric fever in human beings. It can grow from 7 ^{o}C to 37 ^{o}C (Lake *et al*., 2002). About 2500 different serotypes of *Salmonella* are found in different sources, like food, animals and environment. *Typhimurium*, *Newport*, *Javiana*, *Enteritidis* and *Heidelberg* are found common in kids. Associations of *Salmonella* with reptiles are now well-known and risk for infants where they have direct contact with reptiles in their homes (Marcus, 2008). Ingestion of *Salmonella* can lead to Salmonellosis, mostly *Typhimurium* and *enteritis*. Infected worker and food handler can spread *Salmonella* infections in consumers. A national outbreak of Salmonellosis in USA caused by *Salmonella Enteritidis* related to nationally distributed brand of ice cream affect the whole nation and results 250,000 illness (Robert, 1997). Infectious dose of any organisms play important role in disease establishing. *Salmonella* is a potential health risk and infectious dose of this organism are as low as 15 to 20 cells defend on strains and health condition or immune status of person (Bosilevac *et al*., 2009). *Salmonella* are capable to cause a number of disease syndromes including gastroenteritis, bacteremia, and typhoid fever, with the most common being gastroenteritis (Foley and Lynne, 2008).

It has been estimated that almost 95% of the human Salmonellosis are related to the consumption of contaminated product from animal origin such as meat, poultry, eggs, milk, seafood, and fresh produce (Foley and Lynne, 2008). Uncooked or improper cooking of meat lead to food transmits the pathogen. *Salmonella* can be obtained from chicken which are uncooked near bones (Canadian Paediatric Society, 2008). *Salmonella enterica Enteritidis* or to *S. enterica* other than *Enteritidis* or *Typhimurium* were associated with a variety of food vehicles varies from area to area. Most of the zoonotic pathogens are transmitting by food of animal origin. The food borne outbreaks in England and Wales, between 1992 and 1996 show that 27% of these out breaks were associated with poultry and 13% with red meat (Greig and Ravel, 2009). Meat industries particularly poultry meat are becoming common as basic source of meat in different countries, broiler chicken are one of the main type. Broiler chicken carcasses and meat become contaminated with *Salmonella* during its slaughtering processing and even vending on the outlets. Broiler chicken is thought to be commonly associated with the *Salmonella* prevalence and out breaks. *Salmonella* is the main cause of food borne infection associated to eggs and poultry contamination in many countries (WHO / FAO. 2001). Panisello *et al*., (2000) confirmed the association of *Salmonella* species outbreaks with animal origin food, and it improper cooking, storage and cross contamination from contaminated tools to food or food to food also contribute to facilitate the *Salmonella* outbreaks (Panisello *et al*., 2000). Poultry and meat consider as an important primary vehicle of *Salmonella* pathogen to human population, and caused pandemic by *Salmonella agona* and *Salmonella hadar* in 1970s and 1980s associated to poultry (Sumner *et al*., 2004). During 1997, thirty one *Salmonella* strains were isolated from thirty chicken meat samples with two different strains in one case in Albania (Beli *et al*., 2001).

Campylobacter: The unique food-borne pathogen *Campylobacter* is obligate microaerophilic with curved, rod shaped having 16 different species with six subspecies, the most important in which is *Campylobacter jejuni* (WHO. 2011) it can grow from temperature range 31 to 36°C, but some "thermophilic *Campylobacters*" including C. jejuni can grow at high temperature 42°C and stop growth at 30°C (Doyle *et al*., 1981; Gill and Harris. 1983; Hazeleger *et al*., 1998; WHO, 2011). This pathogen is now the leading cause of infection in human beings (Notermans and Verdegaal. 1992; Tauxe, R. V. 1992; Altekruse *et al*., 1999). The human pathogen C. jejuni is a commensal microbe in avian species, including poultry (Rosef. 1983) and an epidemiological study showed the relation of human Campylobacteriosis with undercooked poultry meat (Notermans and Verdegaal. 1992; Altekruse *et al*., 1999). A substantial portion (as much as 98%) of poultry at retail is contaminated with the *Campylobacter jejune* (Stern and Line. 1992). Product other poultry meat can also be contaminated with *Campylobacter* and can play role in human illness, along with untreated water, raw milk, and exposure to live birds and to pets with diarrhea (Notermans and Verdegaal, 1992; Altekruse, *et al*., 1999). *Campylobacter* is the main cause of childhood illness in developing countries and is a common source of gastroenteritis in industrialized countries (Coker *et al*., 2002). Traveler's diarrhea is mostly caused by *Campylobacter* species (Allos 2001). *Campylobacter jejune* and *Campylobacter coli* is most often isolated from diarrhoeal stools in industrialized countries (Engberg *et al*., 2001). Campylobacteriosis are usually self limiting but administration of antibiotic Erythrosine can shorten the duration of diarrhea in children (Salazar *et al*., 1986). In case of chronic infection of Campylobacteriosis or the illness in immunocompromised or transplant patients can cause high morbidity, which can be easily cure with the administration of rapid and effective antibiotic therapy. The drug of choice for is macrolide antibiotic, such as erythromycin, as fluoroquinolone resistance has rapidly increased during the last decade (Engberg *et al*., 2001).

Campylobacter jejuni are counted as the most common causes of acute gastroenteritis. *Campylobacter* infection is rarely associated with systemic invasive infection unlike *Salmonellosis* (Butzler *et al*., 2004).

Campylobacter jejuni is a major cause of food-borne gastrointestinal disease (Griffiths and Park, 1990). There were over 56,000 reported cases of *Campylobacter enteritis* in England and Wales in the year 2001 (http://www.phls.co.uk/topics_az/campylo/data_faecal_ew .htm), and it is estimated that the real incidence may be up to 10 times this figure (Rees *et al*.,1993).

Studies of several *Campylobacter* outbreaks have shown undercooked poultry specifically chicken to be the source of infection (Istre *et al*., 1984; Evans *et al*., 1998). Nevertheless, regardless of these documented outbreaks, *Campylobacter* continues to be a sporadic disease (Phillips. 1995). It can easily colonize on poultry carcasses and is well adapted to live in the avian gut (Alm *et al*., 1993; Gregory *et al*., 1997). *Campylobacter jejuni* can survive and remain live at 4°C (Rollins and Colwell, 1986). Oxygen consumption, catalase activity, ATP generation, chemotaxis, and protein synthesis were also observed at 4°C (Hazeleger *et al*., 1998), this show that the pathogen can tolerate refrigerating temperature. The ability of C. jejune to survive under unfavorable condition as food born pathogen in food is poorly known. C. jejuni is genetically remarkably diverse (Parkhill *et al*., 2000). It is therefore needed to study this pathogen and it different species in order to know the adaptive physiology of the like tolerance to cold and to freeze-thawing, which may differ among different strains (Chan *et al*., 2001).

Since raw or undercooked chicken is considered to be an important risk factor for human Campylobacteriosis (Notermans and Verdegaal, 1992). Even with the implementation of hygiene procedure it is very difficult to prevent *Campylobacter* colonization on the flocks of poultry and farmer always fight with this pathogen to avoid poultry loss and infection control (Newell and Wagenaar, 2000). Once present in a flock, horizontal transfer between birds occurs rapidly, with one study reporting 100% colonization in just 2 days (Humphrey and Jorgensen, 2000).

Increasing drug resistance in food borne pathogens: Drug resistance among the pathogens in common and food borne pathogen in particular is an emerging problem. Many new pathogens are now boasting its resistance against drugs or antibiotic normally in use against pathogenic bacteria. One reason is increasing drug resistance are thought to be the increase of extensive use of antibiotic in animals feed. For example the emerging pathogen *Campylobacter* is now showing resistance against fluoroquinolones, after its use in animal start. In United States of America the food borne pathogen *Salmonella* is becoming multi drug resistant (Robert, 1997).

Fluoroquinolone resistant *Campylobacter jejuni* is also increased in Europe since 1990s. Use of antimicrobial agent for therapeutic purpose in animals and human also contribute to create resistant strains of bacteria. The percentage of antimicrobial resistant *Salmonella* is increased from 17 % in 1970s to 31% isolates in the late 1980s. Infections with multidrug resistant bacteria are harder to cure and take long time as compare to normal case (Altekruse *et al*., 1997). Multi drug resistance strains of *Salmonella* are more dangerous and of great food safety concern. A new multi drug resistance strain of this pathogen called *Salmonella enteric* serotype Newport caused 47 illnesses, 17 hospitalizations and one death in year 2002 associated with contaminated ground beef. Usually a small number of *Salmonella* are multi drug resistant so isolate such strain a multiple number of food sample analysis is necessary (Bosilevac *et al*., 2009).

Salmonella serovar Heidelberg are resistant to ceftiofur, streptomycin, tetracycline, sulfamethoxazole, chloramphenicol and Trimethoprim-sufamethoxazole etc. some antibiotic like ceftiofur are used to control the chicks death which lead to produce drug resistant in some bacteria. This strain of *Salmonella* derived from poultry products is very specifically important due to its ability to cause extra intestinal infection like septicemia and myocarditis (Zhao *et al*., 2008).

Prevalence of *Salmonella, Escherichia coli* and *Campylobacter*: Reported cases of *Salmonella* over the past several years are average 6000 per year in Australia, while the unreported cases is much more than this value. It is thought that the pathogen transfer occurs during slaughtering and dressing the animals, subsequently to food products and then to consumer (Sumner *et al*., 2004). *Salmon*ella species are responsible for the half of the total food outbreaks (Hughes *et al*., 2007). In Australia, News Zeeland, Canada, Europe and America the Salmonellosis epidemics are very common. The epidemiological study of 359 foods borne outbreaks in England and Wales between years 1992 and 1996 show that, 291 outbreaks was caused by *Salmonella*. Salmonellosis was associated with 14 to 20 different food categories in which 27 % are miscellaneous, 17% chicken and 9% are the three most important vehicles. The presence of different species and situation of outbreak related to *Salmonella* are different in different countries. Sixty epidemics caused by *Salmonella* were analyzed in Australia between 1995 and 2000 (Greig and Ravel, 2009). Typhoid is the common enteric fever caused by *Salmonella typhi*. While in case of non typhi Salmonellosis, serotypes other than typhi are responsible to cause. 37,080 out of 37,442 *Salmon*ella isolated in 2003 were *Salmonella* serotype other than typhi. The national rate for *Salmonella* isolate reported was 12.9 per 100,000 populations in year 2003. Serotype such as *Salmonella Mississippi*, *Salmonella Newport*, and *Salmonella Javiana*, were increase in number from 1993 to 2003. Antibiotic resistances also increased among several serotypes of *Salmonella* (Centers for Disease Control and Prevention, 2003; Atlanta Centers for Disease Control and Prevention, 2005).

Salmonellosis incidence decrease to 15% during 1996 to 1998, and show 20% increase from 1998 to 1999.In USA the Salmonellosis incidence were at peak in 1999 with 17% per 100,000 populations (CDC. MMWR. 2000). *Salmonella enterica* identified as the most prevalent cause of food borne diarrhea globally. It has been estimated that *Salmonella enterica* cause 1.4 million illnesses, resulting 16,000 hospitalizations and 600 deaths each year in United States of America. *Salmonella* serovar Heidelberg noticed very common in retail meat particularly in poultry meats. This strain of *Salmonella* is also responsible for causing huge outbreaks in nursing home, hospitals and community (Zhao *et al*., 2008).

The reported infection of most common pathogenic *Escherichia coli* O157:H7 increased and reached to 4,744 in the year 1999. USDA get preventive measure to control this pathogen at farm level which result in decrease number of infection due to *E. coil* O157;H7 and it number decrease 2,674 cases in year 2003. In 2003 CDC received 239 isolates non O157 *E. coli* capable of producing Shiga toxin (Centers for Disease Control and Prevention, 2003; Atlanta Centers for Disease Control and Prevention, 2005).

In year 1999 CDC report that the incidence of *E. coli* O157 infection is ranged from 0.6 in Georgia to 5.8 in New York (CDC. MMWR. 2000). The most common Shiga toxin producing *E. coli* identified by the clinical laboratories are O157, responsible for causing 73,000 estimated infections each year. The percentage of STEC identified with the help of Shiga toxin EIA tests have significantly increased to 59% in 2005 from 33% in 2000. CDC study for non-O157 STEC between 1983 and2002 show the most common serogroups are STEC O26 (22%), O111 (16%), O103 (12%), O121 (8%) and O45 (7%) (Marcus. 2008). Pathogenic *E. coli* have a great potential to cause a verity of diseases like diarrhea and Urinary tract Infections. Shiga toxin producing E. coli (STEC) is involved in large outbreaks in United States, Canada, United Kingdom and Japan (Lee *et al*., 2009).

Outbreaks due to pathogenic *E. coli* in Korea are increased from 4.4% in 2003 to 12.25 in 2007. The pathogenic types of *Escherichia coli* are generally divide in five heterogeneous groups based on their pathogenicity or virulence *Enterotoxigenic E. coli* (ETEC), *Enteropathogenic E. coli* (EPEC), *Enterohemorrhagic E. coli* (EHEC), *Enteroinvasive E. coli* (EIEC), and *Enteroaggregative E. coli* (EAEC). Enterotoxigenic bacteria cause traveler diarrhea and diarrhea in infants, it produce heat-labile (LT) and heat-stable enterotoxins. *Enterohemorrhagic E.coli* cause hemorrhagic colitis with abdominal pain and diarrhea with bloody fecal materials and can lead to death in case of hemolytic uremic Syndrome (HUS). All the above 5 types of *E. coli* are consider pathogenic because of their disease producing ability. *Escherichia coli* O157:H7 is the more active and widespread pathogenic serotype (Lee *et al*., 2009). The percentage of STEC infection which leads to HUS ranges from 5 to 10% in some sporadic cases while its percentage goes to 30% in case of outbreaks. UHS can appear after the infection of diarrhea by *E. coli* which is like pallor, lack of urine formation, swelling and acute kidney failure (Leclerc *et al*., 2002). Pathogen *Escherichia coli* including *E. coli* O157:H7 caused 270,000 cases, however its infections are not always severe and its range from mild to moderate self-limiting gastroenteritis (Zhao *et al*., 2001). Prevalence of *E. coli* O157:H7 are analyzed several time in poultry and its products. Examination of different samples of chicken carcasses in Thailand result that 1% of the sample are contaminated with *E. coli* which are unable to produce Shiga like toxin (Minami *et al*., 2010).

It has been identified in one of recent prevalence study for *Salmonella* and *Escherichia coli* that the prevalence of *Salmonella* is 3.85% in the poultry meat of different super and open market in Bangkok, while the prevalence of *Escherichia coli* was found 25% in the poultry meat of different super and open market around Bangkok (Ali Akbar 2010. unpublished data).

It has been showed in the data obtained from National Disease Surveillance Centre (NDSC) in the Republic of Ireland that 2085 cases of *Campylobacter* were reported in the year 1999 with 57.5 cases per 100,000 person making *Campylobacter* the main cause of foodborne infection in the Republic of Ireland. Food poisoning cases reported other than *Salmonella* in Ireland has risen from 43 to 1554 between 1988 and 2000, peaking at 1673 reported cases in 1999 (Gorman *et al*., 2002). In Spain in year 1999 total number of *Salmonellosis* reported to ‘‘Sistema de Informacio´n Microbiolo´gica’’ (SIM) were 6919 while the cases of Campylobacteriosis were 5191, with an isolation rate of 172 and 129 cases per 1,000,000 population, respectively. *Campylobacter* prevalence has been stated as being over 50%. In one of the study Domınguez *et al*., (2002) reported 49.50% prevalence of *Campylobacter* in the chicken meat in Spain (Domınguez *et al*., 2002). In one of the recent survey conducted by Hussain *et al*., (2007) in Pakistan show that the prevalence of *Campylobacter* is 48% in raw chicken while 10.9% in raw beed and 5.1 % in raw mutton (Hussain *et al*., 2007). 11.6% of *Campylobacter* prevalence was reported by Mahmood *et al*., (2009) in unpackaged/packaged butter and raw milk and 10.8% in unpasteurized cheese while 10% in burfee/Khoa (Mahmood *et al*., 2009). In several European countries *Campylobacter* is more frequently isolated as compare to *Salmonella* as human pathogen. Atanassova and Ring (1999) reported 45.9% *Campylobacter* prevalence in Germany in broiler carcasses (Atanassova and Ring, 1999).

Food safety and Hurdle technologies: Food preservation methods have been developed by the need to extend the stability and safety of food for long time. A number of preservation methods are in practice and is acceptable for consumer and manufacturers with its own advantages and disadvantages. In some cases preservation have

the deterioration effects on nutritional and organoleptic qualities of food. High temperature treatment cause sensory changes in food and flavor change can occurs, while low temperature cause texture change and also allow some Psychrophilic bacteria to grow in the food (Sun-Young, 2004).

Normally the preservation methods are based on single treatment factor fail to deal with the food quality nutritional as well as biological (Aguilera and Chirife, 1994). The multi-target preservation of food is becoming an interesting area of research. The combined methods technology or hurdle technology is composed on applying combine low level of two or more than two preservative factors called hurdles. In such case the stability of the product is the result of combine synergistic effect of two or more preservatives used and no single factor is responsible. This technology are able to minimize the effect of treatments on the food and make the product more acceptable to the consumer as compare to products conventionally treated (Aguilera and Chirife, 1994; Leistner, 1996). The safety and stability of foods depend on the mutual action of preservative factors which the microorganism unable to overcome (Leistner, 1997). This technology is applicable for not only for safety but also for to quality aspects, to maintain the quality and safety it is necessary to adjust the hurdle to it optimal range (Leistner, 1994). Hurdle technology was first introduced by (Leistner, 1997). The hurdle most frequently and effectively using till date in foods are temperature, moisture, water activity, redox potential, chemical preservative and antagonistic microbes. Moreover this list is increasing and more than 50 potential hurdles have been identified in a recent research project in Europe. The non-thermal process means of preservation in the form of hurdles are of more interest now a day. This is more likely to keep the products fresh and safe with less nutritional deterioration and sensory changes (Barbosa-Canovas *et al*., 1995).

Some time the hurdles lead to change the taste of the product and give it new taste properties. A large number of potential hurdle in food have already define including organic acids, bacteriocins, chitosan, nitrate, lactoperoxidase, essential oil, modified atmosphere packaging. Some novel antimicrobial technologies are also frequently using as a hurdle like microwave and radio frequency, pulsed electric field, high pressure, high voltage arc discharge, pulsed light, oscillation magnetic field, ultraviolet light, ultrasound, X-ray, electrolyse NaCl water, ozone (Kim *et al*., 1999). Some bacteria become more resistant and produce stress shock protein. This response of microbes against stress become problematic some time for the application of hurdle technology but it become more hard for bacteria to respond stress produced by different means, because synthesis of several protective stress proteins can exhausted the bacteria metabolically (Leistner, 1995).

While the water activity are reduced, but the products persevered with hurdle technology are known as high moisture products. The methods generally used for the reduction of water in food under hurdle technology are osmotic dehydration, by dipping the products in hyperconcentrated solution (Henriette *et al*., 2005). The synergy become true and effective if the hurdle in a product affect multi-targets like cell membrane, DNA, protein synthesis, water activity, within a single bacteria, so it could be more affective to use multiple preservative in small amount instead of using single preservative in large amount (Leistner, 1997). Lactic acid bacteria can also be use a part of multi factors preservation (Hurdle technology). It produces a wide range of inhibitory compound such as organic acids, hydrogen peroxide, diacetyl and bacteriocins (Rodgers, 2001).

Conclusion

It has been concluded that food borne pathogens particularly meat borne *Salmonella*, *Escherichia coli* and *Campylobacter* have a great concern regarding food safety. Each one of these organisms has its own unique ecology and pathological impacts of the human beings. It is clear that food born infection issues cause by bacteria, viruses or any other parasite is the major cause of public health concern and has social and economical costs throughout the world. A huge number microorganism responsible for the cause food born disease are unknown and it is needed to investigate and monitor all food related infection properly to reveal the real data regarding food borne pathogens in food borne outbreaks. The new way and trends in dealing food, cooking and supply chain of food have also a great impact on the spread of food borne diseases, new challenges are coming to face, particularly new and emerging pathogens are going to be responsible for some food born diseases. Global warming and environmental changes can have an impact on the niches and ecology of common and uncommon pathogens. Changing demography, complication of chemotherapy and immuno-compromised people and improper health and hygiene practices can make the people more susceptible to food born diseases. Meat and all other perishable food are more likely to contribute is this regards. Drug resistant food borne pathogens can cause serious completion in the form of zoonotic and non-zoonotic disease by cross-contamination. Contamination due to infected handlers may be a great risk for the supply chain of food particularly meat. New techniques of preservation are becoming popular to maintain the freshness of food as well as the safety, hurdle technology are fulfilling the requirement of consumer and manufacturers by providing a broad range of food safety and stability.

References

Acheson, D.W. (1999). Foodborne infections. Current Opinion in Gastroenterology. 15: 538-545.

Adak, G.K., Long, S.M. and O'Brien, S.J. (2002). Trends in indigenous foodborne disease and deaths, England and Wales: 1992 to 2000. *Gut*, 51: 832-841.

Adams, M.R. and Moss, M.O. (2008). Food Microbiology Third Edition. University of Surrey, Guildford, UK.

Aguilera, J.M. and Chirife, J. (1994). Combined methods for the preservation of foods in Latin America and CYTED-D project. *Journal of Food Engineering*, London, 22(1-4): 433-444.

Akbar, A. *et al*., (2010). (unpublished data) Asian Institute of Technology, research study May 2010.

Allos, B.M. (2001). *Campylobacter jejuni* infections: update on emerging issues and trends. *Clin Infect Dis*., 15: 1201-1206.

Alm, R.A., Guerry, P. and Trust, T.J. (1993). Distribution and polymorphism of the flagellin genes from isolates of *Campylobacter coli* and *Campylobacter jejuni*. *J. Bacteriol*. 175: 3051-3057.

Altekruse, S.F., Cohen, M.L. and Swerdlow, D.L. (1997). Emerging Foodborne Diseases. *Emerging Infectious Diseases*. 285-293.

Anklama, E. and Battagliab, R. (2001). Food analysis and consumer protection. *Trends in Food Science and Technology* 12: 197-202.

Atanassova, V. and Ring, C. (1999). Prevalence of *Campylobacter* spp. in poultry and poultry meat in Germany. *International Journal of Food Microbiology* 51: 187-190

Barbosa-Canovas, G.V., Pothakamury, U.R. and Swanson, B.G. (1995). State of the art technologies for the stabilization of foods by non-thermal processes: physical methods. In: "Food Preservation by Moisture Control" (G.V. Barbosa-Ca'novas and J. Welt-Chanes, eds.).Technomic Publishing Co., Lancaster and Basel. 493-532.

Beli, E., Duraku, E. and Telo, A. (2001). *Salmonella* serotypes isolated from chicken meat in Albania. *International Journal of Food Microbiology*. 71: 263-266.

Bhunia, A.K. and Lathrop, A. (2003). Pathogen detection, food-borne. McGraw Hill Yearbook of Science and Technology. The McGraw- Hill Companies, Inc. 320-323.

Bosilevac, J.M., Michael, N., Kalchayanand, G.N., and Koohmaraie, M. (2009). Prevalence and Characterization of *Salmonella*e in Commercial Ground Beef in the United States. *Applied and Environmental Microbiology*. 1892-1900.

Butzler, J. P. (2004). *Campylobacter*, from obscurity to celebrity. Clin Microbiol Infect, 10: 868–876.

Canadian Paediatric Society. (2008). Paediatric Infectious Disease Notes. *Cand. J. Infect. Dis. Med.* Microbiology. 19(6): 431-434.

Canadian Paediatric Society. November/December. (2008). Pediatric Infectious Disease Notes. *Can. J. Infect. Dis. Med Microbiology*. Vol. 19(6): 431-434.

CDC. Morbidity and motility weekly report. MMWR. (2000) 49(10).

CDSC. (2002). North West Quarterly Bulletin, July-September.

Centers for Disease Control and Prevention. (2005). Bacterial Foodborne and Diarrheal Disease National Case Surveillance. Annual Report, 2003. Atlanta Centers for Disease Control and Prevention: 6-8.

Chan, K.F., Tran, H.L., Kanenaka, R.Y. and Kathariou, S. (2001). Survival of Clinical and Poultry-Derived Isolates of *Campylobacter jejuni* at a Low Temperature (4°C) *Applied and Environmental Microbiology*, 4186-4191.

Coker, A.O., Isokpehi, R.D., Thomas, B.N., Amisu, K.O. and Obi, C.L. (2002). Human Campylobacteriosis in developing countries. *Emerg. Infect*. Dis. 8: 237-244.

Dominguez, A., Broner, S., Torner, N., Martinez, A., Jansà, J.M., Àlvarez, J., Barrabeig, I., Caylà, J., Godoy, P., Minguell, S., Camps, N., Sala, M.R. and The Working Group for the Study Outbreaks Acute Gastroenteritis of in Catalonia .(2009). Differential Features of Foodborne Gastroenteritis Outbreaks of Known and Unknown Etiology. *Journal of Food Protection*. Vol. 72. No. 9: 1958-1962.

Domınguez, C., Go´mez, I., and Zumalaca´rregui, J. (2002). Prevalence of *Salmonella* and *Campylobacter* in retail chicken meat in Spain. *International Journal of Food Microbiology* 72: 165-168.

Doyle, M. P. and Roman, D.J. (1981). Growth and survival of *Campylobacter* fetus subsp. jejuni as a function of temperature and pH. J. *Food Prot*. 44: 596-601.

Engberg, J., Aarestrup, F.M., Taylor, D.E., Gerner-Smidt, P. and Nachamkin, I. (2001). Quinolone and Macrolide resistance in *Campylobacter jejuni* and C. coli: resistance mechanisms and trends in human isolates. Emerg Infect Dis. 7: 24-34.

Evans, M.R., Lane, W., Frost, J.A. and Nylen, G. (1998). A *Campylobacter* outbreak associated with stir-fried food. *Epidemiol. Infect*. 121: 275-279.

Farzana, K., Akhtar, S. and Jabeen, F. (2009). Prevalence and antibiotic resistance of bacteria in two ethnic milk based products. *Pak. J. Bot.,* 41(2): 935-943.

Foley, S.L. and Lynne, A.M. (2008). Food animal-associated *Salmonella* challenges: Pathogenicity and antimicrobial resistance1. *Journal of Animal Science*, 86: 173-187

Gill, C.O. and Harris, L.M. (1983). Limiting conditions of temperature and pH for growth of "thermophilic" *Campylobacters* on solid media. *J. Food Prot*. 46: 767-768

Gorman, R., Bloomfield, S. and Adley, C.C. (2002). A study of cross-contamination of food-borne pathogens in the domestic kitchen in the Republic of Ireland. *International Journal of Food Microbiology* 76: 143- 150

Gregory, E., Barnhart, H., Dreesen, D.W., Stern, N.J. and Corn. J.L. (1997). Epidemiological study of *Campylobacter* spp. in broilers: source, time of colonization, and prevalence. Avian Dis. 41: 890-898.

Greig, J.D. and Ravel, A. (2009). Analysis of foodborne outbreak data reported internationally for source attribution. *International Journal of Food Microbiology* 130: 77-87.

Griffiths, P.L., and Park, R.W. (1990). *Campylobacters* associated with human diarrhoeal disease. *J. Appl. Bacteriol.* 69: 281-301.

Hazeleger, W.C., Wouters, J.A., Rombouts, F.M. and Abee, T. (1998). Physiological activity of *Campylobacter jejuni* far below the minimal growth temperature. *Appl. Environ. Microbiol*. 64: 3917-3922.

Hedican, E., Hooker, C., Jenkins, T., Medus, C., Jawahir, S., Felfeano. and Smith, K. (2009). Restaurant *Salmonella* Enteritidis Outbreak Associated with an Asymptomatic Food Worker. *Journal of Food Protection*. 72(11): 2332-2336.

Henriette, M.C., Azeredo, H.M.C., Fátima, B.S.A., Deborah, S.G., Ana, A.M., Queiroz. and Gustavo, A. S.P. (2005). Stability of Mango Cubes Preserved By Hurdle Technology. Ciênc. agrotec., Lavras, 29(2): 377-381. http://www.textbookofbacteriology.net/*salmonella*_3.html

Hughes, C., Gillespie, I.A. and O'Brien, S.J. (2007). The Breakdowns in Food Safety Group. Foodborne transmission of infectious intestinal disease in England and Wales, 1992–2003. *Food Control* 18: 766-772.

Humphrey, T. and Jorgensen, F. (2000). Fit to eat? Food scares and safe food production. *Microbiol. Today* 27: 10-12.

Hussain, I., Mahmood, M.S., Akhtar, M. and Khan, A. (2007). Prevalence of *Campylobacter* species in meat, milk and other food commodities in Pakistan. *Food Microbiology*. 24: 219-222.

Istre, G.R., Blaser, M.J., Shillam, P. and Hopkins, R.S. (1984). *Campylobacter enteritis* associated with undercooked barbecued chicken. *Am. J. Public Health* 74: 1265-1267.

Keeratipibul, S., Oupaichit, T. and Techaruwichit, P. (2009). Contamination Profile of *Escherichia coli* and Enterococci in Steamed Chicken Meat Products. *Journal of Food Protection*. 72(9): 1821-1829.

Kijlstra, A., Meerburg, B.G. and Bos, A.P. (2009). Food Safety in Free-Range and Organic Livestock System: Risk Management and Responsibility. *Journal of Food Protection*. 72(12): 2629-2637.

Kim, J.G., Yousef, A.E. and Dave, S. (1999). 'Application of ozone for enhancing the microbiological safety and quality of foods: a review', *J Food Prot*, 62: 1071-1087.

Lake, R., Hudson, A. and Cressey, P. (2002). Risk Profile: *Salmonella* (Non Typhoid) in Poultry (Whole and Pieces). Client Report FW0212. *Institute of Environmental Science and Research Limited*.

Lee, G.Y., Jang, H.I., Hwang, I.G. and Rhee, M.S. (2009) Prevalence and classification of pathogenic *Escherichia coli* isolated from fresh beef, poultry, and pork in Korea. *International Journal of Food Microbiology* 134: 196-200.

Leclerc, V., Dufour, B., Lombard, B., Gauchard, F., Garin-Bastuji, B., Salvat, G., Brisabois, A., Poumeyrol, M., De Buyser, M.L., Gnanou-Besse, N., Lahellec, C. (2002). Pathogens in meat and milk products: surveillance and impact on human health in France. *Livestock Production Science* 76: 195-202.

Leistner, L. (1997). Stable Hurdle Technology Foods and Packaging –Worldwide. *J. Pack. Sci. Technol*. 6 (1).

Leistner, L. (1996). Water activity and hurdle technology. In: "Production of Processed Meats and Convenience Foods" (C. Genigeorgis, ed.). ECCEAMST Publication, (in press).

Leistner, L. (1995). Emerging concepts for food safety. Proc. 41st ICoMST, held August 20-25, 1995, at San Antonio, USA: 321-322.

Leistner, L. (1994). Further developments in the utilization of hurdle technology for food preservation. *J. Food Engineering* 22: 421-432.

Luby, S.P., Rahman, M., Hossain, J., Blum, L.S., Husain, M.M., Gurley, E., Khan, R., Ahmed, B., Rahman, S., Nahar, N., Kenah, E., Comer, J.A. and Ksiazek, T.G. (2006). Foodborne Transmission of Nipah Virus, Bangladesh. *Emerging Infectious Diseases*. 12(12): 1888-1994.

Mahmood, M.S., Hussain, I., Arshad, M.I., Ali, S., Aktar, M., Khan, A. and Mahmood, F. (2009). Seasonal Prevalence of *Campylobacter* species in Milk and Milk Products in Pakistan. *Pakistan J. Zool. Suppl. Ser.,* 9: 227-231.

Marcus, R. (2008). New information about pediatric foodborne infections: the view from FoodNet. *Infectious diseases and immunization*. 79 -84.

Marthim, B. (1999). Food safety challenges in developing countries: the Indian situation. *Food Control*. 10: 243-245.

McDonald, K. and Sun, D.W. (1999). Predictive food microbiology for the meat industry: a review. *International Journal of Food Microbiology* 52: 1-27.

McGill, University. (2010, January 21) Retail meat linked to urinary tract infections: Strong new evidence. *ScienceDaily*. Retrieved February 14, 2010, from http://www.sciencedaily.com/releases/2010/01/100120144005.html.

Minami, A., Chaicumpa, W., Chongsa-Nguan, M., Samosornsuk, S., Monden, S., Takeshi, K., Makino, S. and Kawamoto, K. (2010). Prevalence of foodborne pathogens in open markets and supermarkets in Thailand. *Food Control*, 21: 221-226.

Morn, L., Scates, P. and Madden, R.H. (2009). Prevalence of *Campylobacter* spp. In Raw retail Poultry on Sale in North Ireland. *Journal of Food Protection*. 72(9): 1830-1835.

Newell, D.G. and Wagenaar, J.A. (2000). Poultry infections and their control at the farm level. In M. J. Blaser (ed.), *Campylobacter*, 2nd ed. ASM Press, Washington, D.C. : 497-509.

Notermans, S. and Hoogenboom-Verdegaal, A. (1992). Existing and emerging foodborne diseases. *Int. J. Food Microbiol.* 15: 197-205.

Pandit, D.P., Raina, S., Sangle, S., Bharadwaj, R. (2002). Gastrointestinal Infections In Aids Patients. *International Conference on AIDS*. 14: 7-12.

Panisello, P.J., Rooney, R., Peter, C.Q., Stanwell-Smith, R. (2000). Application of foodborne disease outbreak data in the development and maintenance of HACCP systems. *International Journal of Food Microbiology*, 59: 221-234.

Parkhill, J., Wren, B.W., Mungall, K., Ketley, J. M., Churcher, C., Basham, D., Chillingworth, T., Davies, R. M., Feltwell, T., Holroyd, S., Jagels, K., Karlyshev, A. V., Moule, S., Pallen, M. J., Penn, C. W., Quail, M. A., Rajan- dream, M. A., Rutherford, K. M., van Vliet, A. H., Whitehead, S. and Barrell, B. G. (2000). The genome sequence of the food-borne pathogen *Campylobacter jejuni* reveals hypervariable sequences. *Nature* 403: 665-668.

Paul, S., Slutsker, L., Dietz, V., McCaig, L.F., Bresee, J.S., Shapiro, C., Griffin, P.M. and Tauxe, R.V. (1999). Food-related illness and death in the United States. *Emerging Infect. Dis*. 5: 607-625.

Perni, S., Rijkelt, R. and Zwietering, M.H. (2009). Multi-Tools Approaches For Food Safety Risk Management of Steam Meals. *Journal of Food Protection*. 72(12): 2638-2645.

Perry, W.R., Marsh b, T., Jones, R., Sanderson, M.W., Sargeant, J.M., Griffin, D.D., Smith, R.A. (2007). Joint product management strategies for *E. coli* O157 and feedlot profits. *Food Policy* 32: 544-565

Phillips, C. A. (1995) Incidence, epidemiology and prevention of foodborne *Campylobacter* species. *Trends Food Sci. Technol*. 6: 83-87.

Raghunathan, A., Reed, J., Shin, S., Palsson, B. and Daefler, S. (2009). Constraint-based analysis of metabolic capacity of *Salmonella typhimurium* during host-pathogen interaction. *BMC Systems Biology*. 3:38.

Ravel, A., Greig, J., Tinga, C., Todd, E., Campbell, G., Cassidy, M., Marshall, B. and Pollari, F. (2009). Exploring Historical Canadian Foodborne Outbreak Data Set for Human Illness Attribution. *Journal of Food Protection*. 72(9): 1963-1976.

Rees, J.H., Gregson, N.A., Griffiths, P.L. and Hughes, R.A. (1993). *Campylobacter jejuni* and Guillain-Barre syndrome. *Q. J. Med.* 86: 623-634.

Robert, V.T. (1997). Emerging Foodborne Diseases: An Evolving Public Health Challenge. *Emerging Infectious Disease*. 425-434.

Robert, V.T. (2008). Real burden and potential risks from foodborne infections: the value of multi-jurisdictional collaborations. *Trends in Food Science and Technology*. 19: 18-25.

Rodgers, S. (2001). 'Preserving non-fermented refrigerated foods with microbial cultures—a review', Trends Food Science Technology, 12: 276-284.

Rollins, D.M. and Colwell, R.R. (1986). Viable but nonculturable stage of *Campylobacter* jejuni and its role in survival in the natural aquatic environment. *Appl. Environ. Microbiol*. 52: 531-538.

Rosef, K. (1983). Avian wildlife reservoir of *Campylobacter fetus* subsp. *jejuni*, *Yersinia* spp., and *Salmonella* spp. in Norway. *Appl. Environ. Microbiol.* 45: 375-380

Salazar-Lindo, E., Sack, RB., Chea-Woo, E., Bradford, A., Kay, Zolia, A., Piscoya, R., Leon-Barua. and Yi. A. (1986). early treatment with erythromycin of *Campylobacter jejuni*-associated dysentery in *children. J Pediatric*, 109: 355-360.

Stern, N.J. and Line, J.E. (1992). Comparison of three methods for recovery of *Campylobacter* spp. from broiler carcasses. *J. Food Prot*. 55: 663-666.

Sumner, J., Ravenb, G. and Givney, R. (2004). Have changes to meat and poultry food safety regulation In Australia affected the prevalence of *Salmonella* or of Salmonellosis? *International Journal of Food Microbiology* 92: 199-205.

Sun-Young, L. (2004). Irradiation as a method for decontaminating food. *Internet Journal of Food Safety*, 3: 32-35.

Surveillance for foodborne disease outbreaks-United States, (2006) MMWR Morb. Mortal. Wkly. Rep. 58: 609-615.

Tassios, P.T. and Kerr, K.G. (2010). Hard to swallow-emerging and reemerging issues in foodborne infection. *European Society of Clinical Microbiology and Infectious Diseases.* CMI. 16: 1-2.

Tauxe, R.V. (1992). Epidemiology of *Campylobacter jejuni* infections in the United States and other industrialized nations, In I. Nachamkin, M. J. Blaser, and L. S. Tompkins (ed.), *Campylobacter jejuni*: current status and future trends. American Society for Microbiology, Washington, D.C: 9-19.

Taylor, J.H. (2009). Invaders and turncoats in a complex cosmos. *Gut Pathogens*:1-3.doi:10.1186/1757-4749-1-3

Van, T.T.H., Moutafis, G., Istivan, T., Tran, L.T. and Coloe, P.J. Nov. (2007). Detection of *Salmonella* spp. in Retail Raw Food Samples from Vietnam and Characterization of Their Antibiotic Resistance. *Applied and Environmental Microbiology*, 73. (21): 6885-6890.

Waterman, F.A. and Ibrahim, J.K. (2009). Foodborne outbreaks and agriculture practices: should public health prevention start in the field? *Journal of Environmental Health.* http://www.thefreelibrary.com/Foodborne+outbreaks+and+agricultural+practices:+should+public+health...-a0195287648

WHO / FAO. (2001). Risk characterization of *Salmonella* spp. in eggs and broiler chickens and Listeria monocytogenes in ready-to-eat foods.

WHO. (2000) Food borne disease: a focus for health education.

WHO. (2004) Country Report Foodborne Diseases: Situation of Diarrheal Diseases in Thailand.

WHO. (2007) Food safety and food borne illness.

WHO. (2011) http://www.who.int/mediacentre/factsheets/fs255/en/ visited on 29 march 2011.

WHO (2010) General Information related to microbiological risk in food.
http://www.who.int/foodsafety/micro/general/en/index.html, 09-01-10)

Zhao, C., Ge, B., Villena, J.D., Sudler, R., Yeh, E., Zhao, S., David, G., White, Wagner, D. and Meng, J. (2001). Prevalence of *Campylobacter* spp., *Escherichia coli*, and *Salmonella* Serovars in Retail Chicken, Turkey, Pork, and Beef from the Greater Washington, D.C., Area. *Applied and Environmental Microbiology*, Vol. 67, No. 12: 5431-5436.

Zhao, S., White, D.G., Friedman, S.L., Glenn, A., Blickenstaff, K., Ayers, S.L., Abbott, J.W., Hall-Robinson, E. and McDermott, P.F. Nov. (2008). Antimicrobial Resistance in *Salmonella* enterica Serovar Heidelberg Isolates from Retail Meats, Including Poultry, from 2002 to 2006. *Applied and Environmental Microbiology*. 6656-6662.