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Food-borne Pathogens of Animal Origin-Diagnosis, Prevention, Control and Their Zoonotic Significance: A Review

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Abstract: The term food borne diseases or food-borne illnesses or more commonly food poisoning are used to denote gastrointestinal complications that occur following recent consumption of a particular food or drink. Millions of people suffer worldwide every year and the situation is quiet grave in developing nations creating social and economic strain. The food borne pathogens include various bacteria viz., *Salmonella*, *Campylobacter*, *Escherichia coli*, *Listeria monocytogenes*, *Yersinia enterocolitica*, *Staphylococcus*, *Arcobacter*, *Clostridium perfringens*, *Cl. botulinum* and *Bacillus cereus* and helminths viz., *Taenia*. They also include protozoa viz., *Trichinella*, *Sarcocystis*, *Toxoplasma gondii* and *Cryptosporidium parvum*. The zoonotic potential and the ability to elaborate toxins by many of the microbes causing fatal intoxication are sufficient to understand the seriousness of the situation. The viral agents being host specific their transmission to humans through food of animal origin is not yet confirmed although these animal viruses are similar to that of viruses infecting human. Food-borne bacteria; protozoa and helminthes have complex distribution pattern in the environment and inside the host system. This along with complexity of the maintenance chain and life cycle (of parasites) has made it difficult for epidemiologist and diagnostician to undertake any immediate safety measures against them. Serological and molecular diagnostic tests viz. ELISA, Latex agglutination test, Lateral flow assays, Immunomagnetic separation assays, molecular assays viz. Polymerase Chain Reaction (PCR), multiplex PCR, immuno-PCR, Realtime PCR, Random Amplified Polymorphic DNA (RAPD)-PCR, DNA microarrays and probes are widely used. Along with these LAMP assays, Capillary Electrophoresis-Single Strand Confirmation polymorphism (CE-SSCP); Flow cytometry, FISH, Biosensors, Direct epifluorescent filter technique, nanotechnology based methods and sophisticated tools (ultrasonography, magnetic resonance imaging and chlonangio-pancreatography) have aided in the diagnosis greatly. Most of the food-borne illnesses are self-limiting but in many instances antibiotics are recommended. With the increased drug resistance however use of chicken immunoglobulin, bacteriophage therapy, probiotics and herbs are gaining much importance these days. Adoption of proper prevention and control measures (including cooking procedures; hygiene, strict adherence to HACCP principles, public awareness and disease surveillance and monitoring) are the need of hour. All these have been discussed vividly in this review to help epidemiologists, diagnosticians, clinicians and above all common people so as to enable them avoid negligence regarding such serious issue.

Key words: *Arcobacter*, botulism, bradyzoites, chlonangiopancreatography, campylobacteriosis, food-borne pathogens, ig y, sarcocystis, toxoplasmosis, zoonoses

INTRODUCTION

The term food borne diseases or food borne illnesses or more commonly food poisoning are used to denote gastrointestinal complications that occur following recent consumption of a particular food or drink. There is enormous social and economic strain on societies due to food contamination. Each year around one-third of the

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world population is affected by food-borne pathogens especially in developing countries. Even in developed nation like US, billions are spent in treatment of foodborne diseases caused by major pathogens. Each year 48 million people are affected in US with foodborne illness (Scallan *et al*., 2011; CDC, 2013). International trade of animal products has aggravated the condition. The food borne illness can be of three types i.e. food infection, food intoxication and toxico-infection. The rapid increase in human population and urbanization along with changing food habits has resulted in increase in the consumption of animal product like meat, milk and egg as the animal protein are of higher value and rich in micronutrients like iron and zinc and vitamins (Broglia and Kapel, 2011). By the year 2030, the annual meat production was predicted to be about 376 million tonnes and the per-capita consumption of meat and milk was also expected to increase significantly worldwide (FAO, 2013). This results in increased demand, leading to intensive animal production and processing of products especially mass production and movement of product globally, thereby increasing the chances of contamination and spread of foodborne pathogens. These pathogens can enter the food chain anytime between farm to fork and are classed into bacterial, viral, protozoan and parasitic agents. The pathogens cause disease by consumption of undercooked food and produce illnesses either by their presence or by production of toxins or both. Pregnant women, elderly people, immnocompromised people and children are at higher risk of infection with these pathogens (McCabe-Sellers and Beattie, 2004). The important food borne pathogens of animal origin includes *Salmonella*, *Campylobacter, Escherechia coli, Staphylococcus, Clostridium, Yersisnia, Listeria, Arcobacter, Mycobacterium, Taenia*, *Trichinella*, *Sarcocystis*, *Toxoplasma gondii* and *Cryptosporidium parvum* (Dhama *et al*., 2011a; Dhama *et al*., 2013a). The viral agents being host specific their transmission to humans through food of animal origin is not yet confirmed although these animal viruses are similar to that of viruses infecting human. Contamination of food by infected handlers is considered to be the main mode transmission of food borne viruses (Koopmans and Duizer, 2004) but Hepatis A virus may be transmitted through milk and meat (Velusamy *et al*., 2010). This review particularly focuses on these food-borne pathogens with vivid discussion to help epidemiologists; diagnosticians; Clinicians and above all common people so as to enable them avoid negligence regarding such serious issue.

FOOD-BORNE PATHOGENS OF ANIMAL ORIGIN

***Salmonella*:** *Salmonella* are Gram negative motile bacilli and are one of the leading causes of food borne illness in humans. There are more than 2450 serotypes of *salmonella* which are included under two species *S. enterica* and *S. bongori. Salmonella enterica* is further classed into six subspecies. Food borne salmonellosis also called as non-typhoidal salmonellosis or enterocolitis results in gastroenteritis is caused by ingestion of more than 150 serotypes but *S. Typhimurium* and *S. Enteritidis* being more common (Dhama *et al*., 2011a; Finstad *et al*., 2012; Dhama *et al*., 2013a). Especially *S. Typhimurium* has regained its position as the most common serotype isolated from domestic livestock including pets (Verma *et al*., 2007, 2008, 2011a and 2011b; Lambey *et al*., 2009) even after implementation of *Salmonella* control programmes that actually started way back in the 1990s (European Commission, 1999). Transmission occurs by ingestion of water and food contaminated with animal faeces and also from contaminated food processing equipments. Poultry and poultry products are considered as important source of the organism especially raw shelled eggs (Finstad *et al*., 2012; Dhama *et al*., 2011a, 2013a). Corned beef may act as the source of the germ of typhoid especially in developed country like United Kingdom (Koohmaraie *et al*., 2012). The recently emerged *S. Typhimurium* DT 104 a multi drug resistant definitive type is mainly transmitted through ingestion of contaminated beef. The incubation period ranges from 12-72 h followed by appearance of clinical signs like diarrhea, fever and abdominal cramps. The disease is of self limiting nature and does not require specific treatments but can result in serious complication in young children, old and immuno-compromised individuals (Tribe *et al*., 2002; Smith *et al*., 2005; Finstad *et al*., 2012).

***Campylobacter*:** *Campylobacters* are Gram negative spiral, microaerophilic bacteria belonging to Campylobacteriaceae family. Among campylobacters thermophilic campylobacters are important food borne pathogens especially, *C. jejuni* and *C. coli,* which are the leading bacterial cause of foodborne infections worldwide (Kumar *et al*., 2012a, b). These organisms were isolated from several animal species (Kumar *et al*., 2012a) but poultry act as important source of the organism. There is rapid infection among all birds once a flock is colonised thus significant proportions of raw poultry meat become contaminated with the organism and acting as an important source of the organism. Transmission occurs by handling and consumption of contaminated meat and milk.

Table eggs are not considered as important source of the organism. The organism up on consumption multiplies in the intestinal tract and damages the mucosal epithelium, resulting in self limiting diarrhea and abdominal pain. Several cases may be asymptomatic in nature. The incubation period varies from 3-5 days. *Campylobacter* outbreaks are sporadic in nature and are not associated with mortality but can result in secondary complications like GBS and reactive arthritis (Thorns, 2000; USDA, 2008; Humphrey *et al*., 2007; Dhama *et al*., 2011a; Dhama *et al*., 2013a).

***Escherichia coli*:** *Escherichia coli* are gram negative rods of the family Enterobacteriaceae and are normal commensal organisms, present in the intestinal contents and faeces of both humans and animals. Some strains are pathogenic causing gastrointestinal complications in humans, which are classed into enteropathogenic, enteroinvasive, diffuse adhering, enteroaggregative and enterohaemorrhagic *E. coli* strains. Among the enterohaemorrhagic *E. coli* strains *E. coli* O157:H7 strain also called as Verotoxic *E. coli* strain is an important emerging pathogen food borne pathogen of humans causing outbreaks worldwide (Kiranmayi and Krishnaiah, 2010; Dhama *et al*., 2011a; Dhama *et al*., 2013a). They produce Shiga toxin 1 and 2 (STX-1 and STX-2) also known as verotoxins. Cattle are considered as an important source of the organism with a prevalence rate ranging from 0.1-16% and are shed intermittently in the faces of infected animals. The organisms are also isolated from sheep, horses, dogs, goats and deer. Transmission occurs by consumption of undercooked beef and raw contaminated milk (Fernandez, 2008; Kiranmayi and Krishnaiah, 2010). The incubation period ranges between 2 and 10 days followed by appearance of diarrhea, abdominal pain, vomiting, hemorrhagic colitis, haemolytic uraemic syndrome with acute kidney failure and thrombotic thrombocytopenic purpura (Brynestad and Granum, 2002; Fernandez, 2008; Kiranmayi and Krishnaiah, 2010).

***Listeria monocytogenes*:** *Listeria monocytogenes* are Gram positive intra cellular organisms capable of surviving under refrigeration conditions, low pH and in high salt concentration (Gandhi and Chikindas, 2007). These are also an important emerging foodborne pathogen causing listeriosis (Dhama *et al*., 2013b). The disease is characterized by high mortality rate in affected individuals. Deaths due to listeriosis in human population rose in the 21st century. Transmission occurs by ingestion of food contaminated with the organism. The risk of infection is higher in pregnant women, newborns, older people and immunocompromised persons. Among the food products of animal origin milk and dairy products (Soft Cheese), meat and meat products (sausages) derived from both animals and poultry and turkey along with sea foods act as important source of the organism (Gandhi and Chikindas, 2007; Dhama *et al*., 2013a). The affected individuals show flu like symptoms and may develop septicemia and meningitis. In pregnant women uterine infection can occur resulting in abortion, still birth or fetal infection.

***Yersisnia enterocolitica*:** *Yersisnia enterocolitica* is a small Gram negative bacillus having 14 species in the genera with *Y. enterocolitica* being important as food borne pathogen. Among the more than 70 serotypes of *Y. enterocolitica* only few are associated with disease in humans (O:3, O:9, O:8, O:5, 27) -Yersiniosis characterized by mild fever, diarrhea, abdominal cramps and skin rashes (Lambertz *et al*., 2000). They are psychrotropic in nature able to grow in refrigerated food products including meat, milk, milk products and eggs. Transmission occurs through ingestion of contaminated milk and meat, especially pork. Pigs are considered as an important source of the organism (Lambertz *et al*., 2000; Novoslavskij *et al*., 2013). Poor hygienic practices in handling food product allows contamination of the product by infect handlers. The incubation period ranges from 3-7 days post consumption of contaminated foods. Young children and immuno-compromised individuals are more susceptible to the infection and some infected children may have blood in their stool. The condition persists for few days to week and can also result in chronic enterocolitis and reactive arthritis.

***Staphylococcus*:** *Staphylococcus* is gram positive cocci predominantly transmitted through food of animal origin like milk and milk products, meat including salted meat products. These being commensal organism in both humans and animals cross contamination may also play important role in food borne outbreaks (Dhama *et al*., 2013a). They produce food intoxication by producing 11 different enterotoxins which are produced while the organism grows in the food product. The clinical signs appear within 2-4 h post consumption of the food, characterized by nausea and vomiting mainly, subnormal temperature, chills, headache. The condition is self limiting in nature and recovery occurs rapidly.

***Arcobacter*:** *Arcobacters* are Gram negative spiral, aerobic or aerotolerant bacteria belonging to Campylobacteriaceae family and shows a wide range of habitat. It is an emerging food borne pathogen of increasing public health

concern. The number of outbreaks and incidence unfortunately are unknown as this organism is not usually included in routine clinical investigations. The species of *Arcobacter*, which cause food borne illness, are *A. butzleri*, *A. cryaerophilus*, *A. skirrowii* and *A. cibarus*. They are also isolated from different food animals and poultry worldwide. The organisms are not normal inhabitant of human intestine but have been isolated from patients with endocarditis and peritonitis. It causes signs similar to campylobacters and the signs include self limiting acute diarrhea and bacteremia. Most of these signs persist for a period ranging from two days to several weeks (Phillips, 2001; Lehner *et al*., 2005; Ho *et al*., 2006; Miller *et al*., 2007; Patyal *et al*., 2011; Dhama *et al*., 2013a).

***Clostridium perfringens*:** *Clostridium perfringens* (Type A) is a spore forming Gram positive anaerobic organism especially. Spores can survive cooking processes and play an important role in the possible onset of disease. Transmission occurs through cooked or incompletely meat. The cascade of cooking as well as cooling and re-heating is thereby considered as a risky preparation process. The most risky combination is the preparation of meat-containing dishes that are prepared with a long cooking time and a cooling and reheating step before consumption. It gives the confirmation that after preparation the food is still contaminated with viable cells. More than 10^7 colony forming units per gram (CFU g^{-1}) of food is required to invoke the disease. The clinical signs appear 8-18 h post consumption of the food and the signs include abdominal pain and diarrhea (Brynestad and Granum, 2002; McCabe-Sellers and Beattie, 2004).

***Bacillus cereus*:** *Bacillus cereus* is a gram positive rod-shaped organism facultative anaerobic in nature. Unpasteurized milk and meat pies act as the main source of infection to human. Consumption of large number (10^5 CFU g^{-1}) of viable cells results in development of the symptoms of illness. Two distinct types of illness are produced: a diarrheal form of illness with an incubation period of 10-16 h (approximately) and an emetic form of illness (incubation period: 1-6 h) (Kotiranta *et al*., 2000; Stenfors *et al*., 2008).

***Clostridium botulinum*:** *Clostridium botulinum* is an anaerobic gram positive spore forming bacteria producing one of the most powerful toxins; the botulinum toxin one microgram of which is lethal to human. When the organisms are allowed to germinate under aerobic condition in food stuffs they liberate the toxin causing illness. Fermented uncooked dishes and home canned food substances are the potent source of infection. More than a single person gets affected simultaneously provided multiple people consume such food from the same source. The symptoms appear 12-36 h after eating characterized by dryness of mouth and throat; clear sensorium without fever; bulbar and descending paralysis may lead to death (CDC, 2001; Caya *et al*., 2004).

Parasites: Globally food borne parasites have not received much attention compared to other pathogens due to their long incubation period and are also not regularly suspected and screened in many investigations due to lack of expertise in their detection. But they do exert their impact worldwide and should be given due importance (Dorny *et al*., 2009; Robertson *et al*., 2013). Parasitic like *Taenia solium*, *Taenia saginata*, *Toxoplasma gondii*, *Trichinella spiralis*, *Sarcocystis* spp., *Cryptosporidium parvum,* etc., could be transmitted through the foods of animal origin.

Taeniasis: The cestodes *Taenia solium* and *T. saginata* can be spread through meat pig or bovine origin. The eggs of the parasite are resistant to most conventional chemical disinfectants and act as the source of infection to animals. Pigs (*Taenia solium)* and cattle (*T. saginata*) are the important reservoirs. Humans interestingly act as definitive host for both these parasites. Pastures fertilized with human sewage may act as the source of transmission to animals. The larval stages of the parasite called as cysticercus can also infect and develop in human (*T. solium* only). Presence of the adult parasite in the intestine causes abdominal discomfort and weight loss and anal pruritis due to excretion of the segments and eggs of the parasite. The cysticercus infecting human can develop in any organ but its lodgment in brain causes neurocysticercosis which results in epilepsy (Van Kerckhoven *et al*., 1998; White, 2000).

***Trichinella*:** Trichinellosis is a zoonosis and cosmopolitan in distribution. This nematode parasite occurs worldwide, with *T. spiralis* being the most common species reported. Human gets infected by ingesting the encysted larvae of the parasite present in the meat of food animals especially pigs which are considered as important source of the organism. Apart from pigs, the horse flesh or dog meat may also act as the source of infection. Most of the infections in the European Union have occurred to consumption of improperly cooked horse flesh originating from Eastern Europe and North America. The condition consists of intestinal phase and muscular phase which is characterized by muscular pain and eosinophilia (Macpherson *et al*., 2000).

***Sarcocystis*:** *Sarcocystis hominis* and *S. suihominis* are intracellular protozoa with humans acting as definitive host. Humans acquire infection after ingestion of raw or undercooked meat from cattle or pigs. The signs include loss of appetite, nausea, abdominal pain, bloat, watery diarrhea, vomiting, difficulty in breathing, muscular pain, fever, rash and cardiomyopathy (Fayer, 2004; Solaymani-Mohammadi and Petri, 2006).

***Toxoplasma gondii*:** *Toxoplasma gondii* a protozoan parasite capable of infecting all warm blooded animals including humans and is probably the most wide spread parasite on earth infecting half a billion of people (approx.). Infections may locally depend upon meat consumption habits apart from population density of cats. Food borne transmission occurs ingestion of bradyzoites (tissue cyst) present in the meat of food animals. Pigs are considered as an important source and undercooked pork consumption carries the risk of acquiring the infection. Pregnant women and immune-compromised individual are at higher risk and in immunocompetent individuals the disease is subclinical in nature. In congenital form of the disease can result in abnormalities in newborn like hydrocephalus, blindness, epilepsy and others (Fayer, 1994; Dubey, 2002; Solaymani-Mohammadi and Petri, 2006; Dubey and Jones, 2008).

***Cryptosporidium parvum*:** *Cryptosporidium parvum* are an obligate intracellular extracytoplasmic parasite capable of infecting humans and animals. Calves, lambs, goats and swine are infected with the *C. parvum* and poultry gets with *C. baileyi* and *C. meleagridis*. Transmission occurs mainly through water, but due to their higher prevalence and ubiquitous distribution consumption of contaminated raw milk and meat (Sausages) could also result in infection. Contamination occurs with the oocyst directly from infected animals faeces or through water or handlers. The infective stage thick walled sporualted oocyst is released in the faeces of infected host and can infect new host up on consumption. Their life cycle also consist of an auto infective phase thin walled sporulated oocyst which can cause re-infection of the host. The oocysts are highly resistant to disinfectants such as chlorine bleach which enable them to survive for a long period of time without loosing infectivity. In immunocompetent persons it causes diarrhea for short period but in immunocompromised persons the diarrheal episode can be prolonged and can be life threatening. The incubation period is variable and is usually prolonged (Laberge *et al*., 1996; Dawson, 2005; Teresa *et al*., 2006).

Diagnosis: The main obstacle in the detection of the pathogen is the variety of foods involved in the outbreak, similarity of the clinical symptoms exhibited, short duration of the clinical symptoms and reduced fraction of affected people seeking medical attention. Rapid and definitive identification of the causative organism and the route of infection are important in the prevention and control food borne outbreaks. The physician should observe the characteristic clinical signs and should collect the appropriate clinical samples and send to specialized labs for identification of the causative organism. He should collect proper case history like types food consumed, place of consumption, involvement of others who have consumed the same food, if possible collect the food sample involved to identify the source of outbreak. Differential diagnosis of the cases is also important to differentiate it from similar conditions. The conventional methods of isolation of the causative organism by cultural techniques are time consuming (Verma *et al*., 2011b) and the screening for viral etiology is rarely carried out. The method employed may vary with the type of organism suspected in the case and the physician should indicate the appropriate method to be employed to hasten the diagnosis process. The microbiological screening of stool, blood, food samples and vomitus can be carried out to identify the causative organism.

With the advent of molecular techniques the detection of food borne pathogens could be made within a short period of time using methods like Latex agglutination test, Lateral flow assays, Immunomagnetic separation assays, Polymerase Chain Reaction (PCR), multiplex PCR, immune-PCR, Realtime PCR, DNA microarrays, Loop mediated isothermal amplification (LAMP) assays, Capillary Electrophoresis-Single Strand Confirmation polymorphism (CE-SSCP), Flow cytometry, Fluorescence In Situ Hybridization (FISH), Biosensors, Direct epifluorescent filter technique, nanotechnology based methods. (Olsen *et al*., 1995; Malorny *et al*., 2003; Oh *et al*., 2008; Velusamy *et al*., 2010; Arora *et al*., 2011; Habtamu *et al*., 2011; Verma *et al*., 2011b, Dhama *et al*., 2012). After identification of the causative agent its source should also be investigated in food borne outbreaks using various conventional and molecular typing methods (De Boer and Beumer, 1999). With respect to parasitic food borne pathogens their diagnostic investigation is still challenging as they are not usually suspected in many cases and their clinical signs also do not appear immediately in most cases. Selection of the appropriate direct or indirect method of detection is important in specific situations that include: surveillance along with disease outbreak investigations and routine diagnostics of parasitic diseases (Gajadhar and Forbes, 2002). The classical coprological techniques lack sensitivity unless repeated several times. Serological tests

viz., Enzyme Linked Immunosorbant Aasay (ELISA) and molecular detection techniques: DNA probe, polymerase chain reaction, randmly amplified polymorphic DNA- PCR (RAPD-PCR) (specifically for Trichinella) etc., Ultrasonography or sophisticated tools like magnetic resonance imaging and chlonangiopancreatography are especially valuable for detection of cysts in human (Schantz *et al*., 1998; Macpherson *et al*., 2000; Chen *et al*., 2003).

Treatment: Most of the food-borne illnesses are of self limiting in nature and are managed by supportive therapy like fluid therapy to correct the hydration status of the affected individuals (Sharma *et al*., 2008). Use of antibiotics in the treatment of food borne illness is recommended only under severe conditions and should be employed if specific diagnosis is established. Recently, there is increase in the emergence of drug resistance and multiple drug resistance (Srinu *et al*., 2012). Judicious use of antibiotics thereby should be made with proper knowledge about the sensitivity pattern of the organism (Kumar *et al*., 2011; 2012a). Use of newer and alternative therapeutics like probiotics, avian egg antibodies, bacteriophage therapy and herbal remedies need to be explored and promoted (Tiwari *et al*., 2011; Mahima *et al*., 2012; Tiwari *et al*., 2012; Dhama *et al*., 2013c). Probiotics have been found to enhance immunity and prevent particularly those pathogens originating from food that cause enteric infections viz., *S. aureus* and *Clostridium perfringens* (Dhama *et al*., 2008, 2011b). A multi strain probiotic should be used timely for best results. Again chicken egg yolk antibodies are useful in certain food-borne illness. The specific antibodies (IgY) after immunization are transported to the egg yolk and they can then be separated without sacrificing the bird. Oral administration of IgY has been tried and found useful in treatment of human and animals against food-borne bacteria like enterotoxigenic *Campylobacter* spp. and *Salmonella* spp. (Mine and Kovacs-Nolan, 2002; Kovacs-Nolan and Mine, 2004; Michael *et al*., 2010). Bacteriophages are viruses that kill bacteria by lysing them and can be used against food-borne pathogens such as *E. coli*, *P. aeruginosa, Salmonella* spp., *Campylobacter jejuni* and *C. coli* and *Listeria monocytogenes* (Lu and Koeris, 2011; Sulakvelidz, 2011; Tiwari *et al*., 2011; Tiwari *et al*., 2012). A number of plants as well as plant extracts and constituents have been identified as having anti-microbial activities and are often considered as immune enhancers and thus find their applicability in present context. Spices such as onion as well as garlic and ginger; mustard and red chilli; spices viz. turmeric, clove, cinnamon and saffron; others like curry leaf and fenugreek are some medicinal plants and dietary constituents having antimicrobial property (Mahima *et al*., 2012). In addition immune stimulating and antioxidant properties possessed by them help facilitate recovery (Rajendhran *et al*., 1998; Rios and Recios, 2005; Tilak and Devasagayam, 2006; Dhama *et al*., 2013c).

Prevention and control: Food hygiene legislations affect all food businesses including caterers and farmers; manufacturers and retailers. As the infected animals and poultry would subsequently result in contamination of the product obtained from them, therefore prevention and control measure are to be adopted to reduce infection burden in animals and in the processing steps of the food product obtained from the food animals till consumed (Sinell, 1995; Dhama *et al*., 2011a). Usually food-borne microbes are killed by cooking or chilling. Strict adherence to the food hygiene practices during production and storage and also during transportation and preparation of food is a mandate. The most novel prevention and control strategies have been described below:

- Proper cooking of the food product is very important measure. Moist heat treatment reduces the chance of spread of bacterial toxins
- Proper cooling and refrigeration of food items along with maintenance of keeping quality (especially to prevent the growth of *Clostridium perfringens*)
- Avoiding cross contamination of cooked food is also equally important
- Adopting good husbandry practices including of proper biosecurity measures, cleaning, sanitation, hygiene, disinfection, quarantine, therapeutic regimens and appropriate vaccination programme
- Precautionary measures to check for pathogen spread by people, vehicles, equipments, feed, litter, water, vermin (rats/mice), insects/beetles, wild birds, animals entering/present in the farm
- Judicious use of suitable antibiotics for treating diseases. Misuse and over/low dose of antibiotics should be discouraged
- Chlorination of drinking water
- HACCP principles in production and processing of animal products
- Good kitchen hygiene practices and adequate cooking of the product
- Avoiding cross contaminations of cooked with other raw food materials
- Avoid consumption of raw/ uncooked products especially milk
- Appropriate and timely medical advice/treatment of affected individuals should be followed

- Regular reporting of the outbreaks to local health departments
- Appropriate trade restrictions should be implemented in the event of an outbreak of food-borne pathogen
- Enforcement of disease surveillance and monitoring programmes
- Last but the least is the promotion of health education

CONCLUSION AND FUTURE PERSPECTIVES

The inability of non-industrialized countries to keep pace with population growth and migration to urban areas and demand for clean and safe food increases the burden of ill health due to microbes, helminthes and protozans. Importantly these pathogens are of zoonotic significance. Serology and molecular diagnostics along with sophisticated tools have made the detection of these illnesses easier that also in the early stage of the infection. Increase in drug resistance has led to development of certain innovative therapeutic approaches like use of chicken egg yolk antibodies and bacteriophages. Use of probiotics and herbs available in our day-to-day life helps to keep the side effects at minimum level and thus are becoming popular in treating many of these microbial and parasitic infections. There is possible chance of further expansion of the diversity of the pathogens for which genomic epidemiology approaches are matter of concern. But nothing seems well without undertaking proper preventive and control measures. To prevent food-borne illness is of utmost importance as not only the microbes and parasites but also the toxins elaborated by them can lead to fatality. In this regard bringing expertise together from veterinary, food and clinical microbiology and parasitology may help in unravelling the complexities and to identify areas amenable to intervention and prevention. Food hygiene practices must be adhered to during production and storage as well as transportation and preparation of food which help to minimize the growth and spread of pathogens in most instances. Effective implementation of the food hygiene legislation will have a positive impact on food businesses including caterers, farmers; manufacturers and retailers. Preventing the spread of the diseases from human to animal population is equally important due to zoonotic threat posed by many of them. Special emphasis must be given to public education and mass awareness programmes. This will ensure disruption of the chain of maintenance of pathogens in the environment and ultimately in the food we eat.

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