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Food-borne Zoonotic Diseases

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Preface

The food-borne zoonotic diseases (FBZDs) are widespread and pose a significant threat to public health. These are caused by consumption of food or water contaminated by pathogenic microorganisms such as bacteria, viruses, prions, protozoa, fungi, helminth, rickettsia and microsporidia and parasites. Many of these micro-organisms are commonly found in the intestines of healthy food-producing animals. The risks of contamination are present from farm to fork and require prevention and control throughout the food chain.

The FBZDs remain a significant cause of morbidity and mortality and pose consequential obstacle to socio-economic development. While many of these may be self- limiting, some may be very severe leading to mortality particularly among children, pregnant women and older persons. In the US alone, about 76 million people fall sick, more than 300,000 are hospitalized, and over 5,000 die every year from food-borne illness. In India, the burden of food-borne disease is not precisely known as most of these go unreported, except a few with high morbidity and/ or occurring in urban areas. It will be crucial to develop an adequate food safety system ahead to avoid increase in burden of food-borne illness. As per a recent report, unsafe food costs India as high as US$28 billion a year, underlining the needless high economic burden caused by FBZDs. Further, food safety is no longer merely a public health issue, it is also a matter of concern for international food trade due to risk of cross-border transportation of contaminated foods.

Realizing the growing public health burden of unsafe food, the National Academy of Agricultural Sciences (NAAS) organized a BSS on *Food-borne Zoonotic Diseases* on November 21, 2019 to help evolve a comprehensive strategy for strengthening food-borne disease surveillance, management and mitigation. The BSS was attended by a galaxy of eminent scholars, and the deliberations were enriched by their lively presentations and discussions. This policy paper is an outcome of the above deliberation. I gratefully acknowledge the contribution of Dr. A.K. Srivastava, Convener and Dr. R.K. Singh, Co-Convener of BSS, distinguished participants, and reviewers. My thanks are also due to Dr Kusumakar Sharma and Dr P.S. Birthal for their editorial support. I am hopeful that this document will be useful to the fellowship, policy makers and all other stakeholders.

(T. Mohapatra)
President, NAAS

Food-borne Zoonotic Diseases

INTRODUCTION

Food-borne zoonotic diseases (FBZD) pose a constant threat to public health, socioeconomic development and international trade. More than 200 known diseases are transmitted to human beings through food contaminated by pathogenic microbes such as bacteria and their toxins, viruses and parasites. The World Health Organization (WHO) in its initiative to estimate the global burden of food-borne zoonotic diseases reported illness caused by 31 food-borne zoonotic hazards, and estimated over 600 million illnesses and 4,20,000 deaths due to FBZD in 2010 (WHO, 2015). The disease burden was the highest in Africa (43%), followed by South-East Asia (24%) and Eastern Mediterranean (16%) sub regions. Around 40% of the FBZDs were reported from children under 5 years of age. The highest rates of under-5 mortality due to diarrhea were in sub-Saharan Africa and South Asia with India accounting for 1,05,000 deaths in the year 2015 (Troeger *et al*., 2017). Food-borne zoonotic diseases cost India about US$ 28 billion (Rs. 1,78,100 crore) or around 0.5% of the gross domestic product (GDP) every year (Kristkova *et al*., 2017). It is estimated that the current FBZD burden in India represents about 100 million cases per year. This corresponds to one in 12 people falling ill, which could be an underestimate as not all the cases are reported or recorded, and detailed information on the economic costs of food-borne diseases are largely missing.

The risk of food-borne zoonotic illness has been rising due to several factors including pathogen behavior, rapid population growth and an increased global trade in foods and farm animals from the countries where appropriate microbiological safety procedures are not being followed or implemented. The improved transport logistics and conditions facilitate some microorganisms to survive on food products for longer periods and reach consumers in a viable form. The change in eating habits of consumers, for example, the consumption of lightly cooked food and a shift from low-to-high protein-based diets *(like meat and fish products)* has also increased the probability of occurrence of food-borne zoonotic illnesses. Further, the increased movement of human population facilitates easy spread of pathogens. These factors have escalated the severity of food-borne diseases and their impacts on health of the communities. Therefore, preventing illness and deaths due to food-borne zoonotic diseases remains a major public health challenge. Lack of accurate epidemiological data on the incidence and cost of food-borne diseases, particularly in the developing countries, has resulted in sketchy policies and resource allocations for mitigation of food-borne diseases. Further, the increasing antimicrobial resistance in bacterial pathogens all along the food chain has also impacted the public health.

Considering the severity of the problem, a brain storming session on *Food-borne Zoonotic Diseases* was organized by the National Academy of Agricultural Sciences on November 21, 2019, to discuss strategic interventions to prevent FBZDs, and suggest a way forward to enable the governments to allocate resources and take appropriate measures for their prevention and control. This paper summarizes the main conclusions that emerged from the discussion.

BACTERIAL FOOD-BORNE ZOONOTIC PATHOGENS

Human diarrheal diseases are mostly caused by bacterial food-borne infections (64%) followed by viral (24%) and protozoan (12%) infections. During the last two decades, *Salmonella* spp., *Campylobacter* spp. and *E. coli* were reported to be the major food-borne bacterial agents. The recent estimates from the WHO revealed that *Campylobacter* spp. (27%), Enterotoxigenic *E. coli* (25%), non-typhoidal *Salmonella enterica* (23%), *Shigella* spp. (15%) and Enteropathogenic *E. coli* (7%) are the major diarrheal disease pathogens. *Campylobacter* spp. has been estimated to cause 96 million cases of illness in 2010. Globally, about 4.6 billion cases of infectious diarrhea and 1.6 million deaths are reported annually due to contaminated food and water (Pires *et al*., 2015).

Campylobacter spp.

A report of Food Borne Epidemiology Reference Group of World Health Organization estimates global median of 95,613,970 cases of campylobacteriosis (WHO, 2015). In South East Asian Region D (SEAR-D), which also includes India, the median 16,379,442 cases have been estimated. Global median deaths estimated due to campylobacteriosis are 21,374 including 5,410 deaths in SEAR-D region.

The prevalence and public health impact of *Campylobacter* in India is firmly established, although the estimates for endemic and economic losses are sketchy. Sporadic studies conducted in the country show the presence of *Campylobacter* organisms in foods of plant origin, various species of animals, birds and foods of animal origin including milk (Kumar *et al.,* 2015). Troeger *et al*. (2017) estimated nearly 10,211 deaths in children below 5 years of age due to campylobacterioses in India. The complications of infection include meningitis, urinary tract infections, reactive arthritis and Gullian Barré syndrome, a nerve disorder that causes muscle weakness and paralysis of limbs. Major sources of infection include under-cooked poultry meat, pets (*especially young puppies*), water and raw milk. Several studies in India have estimated the occurrence of *C. jejuni* and *C. coli* in the range of 4.42-28% in chicken meat, 1.3-4.4% in cattle milk, 3.6-25% in meat, 13.52-22.64% in water, 2.35-25% in human diarrheal and 0.56-8% in healthy human faecal samples (Outreach Programme on Zoonotic Diseases (OPZD) Annual Reports, 2014-2019). Macrolides and fluoroquinolones are the drug of choice for treatment of human diarrheal cases. However, increasing instances of antimicrobial resistance have been reported against multiple drugs. An increasing trend of multi-drug resistance of 2.2% in 1994, 30.6% in 2005 and 51.33% in 2016 has been observed in *Campylobacter* spp. isolates from diverse origins in India (Kumar, 2016). Therefore, a nation-wide surveillance of campylobacterioses cases is required, along with type of strains isolated from both human and animals. Preventive measures such as rearing of campylobacter-free poultry flocks and good hygienic practices throughout the production chain may limit the transmission of the pathogen.

Salmonella

Salmonella is the second leading causative agent of food-borne zoonotic illness in most developed countries and the most common reason for food-borne zoonosis in developing countries. *Salmonella enterica* subsp. *enterica* causes 99% of the human and animal infections. It is estimated that approximately 78.7 million cases of food-borne illness occur due to non-typhoidal *Salmonella* globally, leading to 59000 deaths (WHO, 2015). *Salmonella* has wide range of livestock species (poultry, cattle, and pigs) as host and the infected animals act as a reservoir of zoonotic salmonellae. Contaminated eggs, poultry meat and pork are common vehicles of salmonellosis to humans. In India, the foods of animal origin are considered as the main source of infection, with other contributing factors such as inadequate cooking, lack of refrigeration, slow cooling of food and inadequate reheating before serving. Various studies have documented prevalence of *Salmonella* spp. in foods of animal origin including meat (4-12.4%), carabeef (1.25%), pork (10%), chicken (14.89%), poultry litter (1.73-28.33%) and water (3.4-14.89) in India (OPZD Annual Reports 2014-2019). The non-typhoidal *Salmonella* serovars, especially of Typhimurium, Enteritidis, Heidelberg and Newport have been reported in many outbreaks of human salmonellosis around the globe, which have been linked with the consumption of *Salmonella*-contaminated foods of animal origin. Furthermore, the emergence of several clones of *Salmonella* resistant to multiple antimicrobials worldwide underscores a significant food safety hazard (Jajere, 2019). A detailed surveillance followed by risk assessment studies is imperative to control salmonellosis.

Escherichia coli

E. coli has wide range of hosts. Seven different groups of *E. coli* strains have been isolated so far from gastrointestinal diseases, of which foodborne infections are mostly associated with Enterotoxigenic *E. coli* (ETEC) and Enteropathogenic *E. coli* (EPEC) strains, although Shiga-toxigenic *E. coli* (STEC) causes more severe disease leading to mortality. Among the STEC strains, *E. coli* O157:H7 is widely recognized as an important cause of food-borne illness. The clinical outcomes of STEC infections would be mild to severe diarrhea and hemolytic-uremic syndrome. Cattle are the principal reservoirs of STEC and beef has been implicated in several global outbreaks. ETEC strains have also been isolated from carabeef, dung, feces of diarrhea patients and river water in India. The presence of antimicrobial-resistant *E. coli* other than STECs in foods of animal origin is also an emerging public health concern. Antimicrobial-resistant *E. coli* strains that produce extended-spectrum â-lactamases (ESBLs) are of particular public health concern. ESBL-producing *E. coli* have been documented in feces of healthy poultry and retail meat from several parts of the world including India. Occurrence of *E. coli* have been documented in cattle milk (1-11%), water (2.6-33.3%), meat and meat products (24.10%), poultry eggs (10%), carabeef (9%), chicken meat and giblets (1.33%). In a study conducted on street-vended foods, a higher presence of *E. coli* was observed in raw food samples (60.62%), followed by environmental samples (46.73%) and ready-to-eat foods (42.99%), of which 26.49%, 6.97% and 15.21% samples, respectively harboured ESBL producers. ESBL *E. coli* was also detected in finished food products like salad, chutney and paneer (Sivakumar, 2016).

Listeria monocytogenes

Listeria monocytogenes is one of the most virulent food-borne pathogen, which causes Listeriosis - a serious but preventable and treatable food-borne zoonotic disease with 20-30%

fatality. According to WHO (2015) estimates, annually 14,169 cases of food-borne illness and 3,175 deaths occur globally due to this disease. The survival capability of *L. monocytogenes* in a wide range of pH, salt concentration and other processing and refrigeration conditions poses potential threat to public health. Processed, refrigerated and ready-to-eat foods of animal origin are the major sources. Pregnant, elderly or immuno-compromised persons are at a greater risk of infection. *L. monocytogenes* has been reported also from the cases of spontaneous abortion in humans. The occurrence rates of 3.5-15.7% in water and 5.21-20.5% in meat have been recorded for *L. monocytogenes* in different studies (OPZD Annual Reports 2014-2019). Many studies (Barbuddhe *et al*., 2012; Shakuntala *et al*., 2019) have reported occurrence of *L. monocytogenes* in animal source foods such as milk and its products (1–23%), chevon (0–17%) poultry meat (8–15%) and pork (1.3-2.8%). Further, the existence of multidrug-resistance and biofilm-forming capacity of *L. monocytogenes* isolates is also a cause for public health concern. The clinical outcomes of listeriosis include perinatal and non-perinatal related symptoms of septicemia, meningitis, neurological consequences, still birth, and death. *Listeria* spp. isolates from food have been found to be resistant to antibiotics such as penicillin, ampicillin, tetracycline, and gentamicin, currently being used in the treatment of human listeriosis (Olaimat *et al*., 2018). Further research is needed on alternative therapies to treat listeriosis and for better understanding of bacterial persistence and survival over a wide range of temperature outside mammalian hosts.

Vibrio spp.

Among more than 100 species of *Vibrio, V. cholerae, V. parahemolyticus* and *V. vulnificus* cause food-borne infection. The reservoirs include normal flora of brackish water, aquatic flora (*macrophytes, microphytes*) and fauna (*zooplanktons, crustaceans*), humans and animals. Raw oysters, crustaceans, crabs and under-cooked mussels are common sources of *Vibrio* spp. infection in human. *V. cholerae* is found in oysters for weeks under refrigeration and for more than 2 weeks in dairy products, including soft desserts, and cakes. Complications of infection include severe dehydration, cardiac and circulatory failure *(that occur due to loss of potassium)*, septicemia, wound infection, ear infection, cellulitis, peritonitis, necrotizing fasciitis, cholecystitis, endophthalmitis and meningitis. Various studies have documented occurrence of *V. cholerae* (3.45-57.38%) and *V. vulnificus* (2.3-38.5%) in marine fish, clams, shell fish, water, brackish water fish, and aquatic environment. The occurrence of *V. parahemolyticus* was found to be between 6.9-56.09% in crab, shrimps, fish, shell fish in coastal regions of India. Although the data on burden of *V. cholerae* in India is well documented (Ali *et al*., 2017), the food-borne burden due to other *Vibrio* spp. is sketchy and require focused studies to estimate the true burden.

Aeromonas spp.

Aeromonas spp. are ubiquitous aquatic bacteria, recognized as important human pathogen due to its frequent prevalence in diverse foods, particularly in seafoods. The reservoirs of the species include wide range of fish, environment and water. This organism has been isolated from meat, raw milk, poultry, fish, shellfish, and vegetables. Seafood products are more commonly contaminated because of the widespread occurrence of these bacteria in the marine environment. *Aeromonas* spp. can also enter the food chain through cross-contamination during processing from biofilms on food-contacted surfaces. Batra *et al*. (2016) estimated 76 cases per million population in Asia. The occurrence rate of *Aeromonas* spp. in various samples was reported in the range of 22.2-50% in fresh water fish, 18.34% in prawns, 46.67% in frozen fish, 10-22.5% in chicken and 11-16.52% in different water sources (Brahmabhatt, 2011; Didugu *et al*., 2016).

Brucella spp

Brucellosis is an important economic concern with losses occurring in the human, livestock and wildlife populations. In India, brucellosis caused a median loss of USD 3.4 billion to the livestock sector, of which 96% was attributed to the dairy sector alone (Singh *et al*., 2015). The annual median losses due to human brucellosis were estimated to be Rs 627.5 million in India (Singh *et al*., 2018). Food-borne infection occurs through consumption of infected unpasteurized milk, milk products, or meat. Cheese prepared from unpasteurized milk from endemic areas is a particular risk for tourists**.** The milk of infected sheep, goats and cattle may contain a large number of viable organisms, which become concentrated in products such as yogurt, paneer and cheese. In 80% of the infected dairy animals, the organism localizes in the supra-mammary lymph nodes and mammary glands, and they continue to excrete the pathogen in milk throughout their lives intermittently acting as carriers (OIE, 2016). Various studies have reported the occurrence of brucellosis in the range of 4.35-55.6% in cattle milk samples in India. The prevalence rate was found to be higher in unorganized farms. Recent studies have indicated resistance of *Brucella* spp. towards commonly used antibacterial drugs such as *rifampicin* and *co-trimoxazole*, which is a matter of concern and calls for judicious use of antibiotics (Doimari *et al*., 2018). Although numerous studies have been conducted on sero-prevalence of brucellosis in different livestock species, only a few have focused on the occurrence of *Brucella* spp. in foods. Studies on estimates of potential risk of brucellosis through foods need to be extensively carried out.

Clostridium perfringens

C. perfringens is an important pathogen of both humans and animals due to its presence in soil, water, and dust, besides its presence in their intestinal tracts. Among the 5 types of *C. perfringens*, type A is associated with food poisoning and harbours enterotoxin genes. Meat and poultry products are common source of poisoning. Inadequate heating, survival of spores and post-production temperature abuse, especially in large scale preparation of foods, leads to outbreaks of infection in humans. Prevalence of the microorganism in different meats has been estimated to be in the range of 40-85% in carabeef, 35-75% in chevon, 30-75% in poultry, 20-85% in ready-to-eat meat and poultry products in India.

Mycobacterium tuberculosis and *M. bovis*

According to WHO, about 30% of total global tuberculosis cases are found in India. In addition to M. *tuberculosis*, *M. bovis* (bovine tuberculosis) plays a crucial role in spread of tuberculosis in

India, where 70% of the human population resides in rural areas. Consumption of unpasteurized raw milk is the major risk factor for its transmission. There may be ~ 21.8 million infected cattle in India with bovine tuberculosis (Srinivasan *et al*., 2018). In another study to estimate the occurrence of bovine tuberculosis in three high-risk populations, *M. bovis* was detected in samples from 11.4% farmers, dairy workers, and livestock keepers, 8.9% zookeepers and animal handlers and in 12.6% residents of TB endemic areas (Bapat *et al*., 2017). In all these cases, previous contacts with active TB cases and raw milk consumption were found to be important determinants of bovine TB. Many studies have documented the presence of *M. tuberculosis* in milk in the range of 4.8-52.17%, depending on the regional endemicity. (OPZD Annual Reports 2014-2019). There is an urgent need to study the contribution of *M. bovis* towards human tuberculosis burden in India.

M. avium sub-sp. *Paratuberculosis*

M. avium sub-sp. *Paratuberculosis* (MAP) is responsible for causing paratuberculosis and is a major pathogen of livestock globally including India. The animals from sub-clinical to clinical stage continue to shed MAP bacilli in their milk and feces. Among the 26,000 domestic livestock screened in India, the bio-load of MAP was found in 43% cattle, 36% buffaloes, 23% goats and 41% sheep. Further, mass screening of 28,291 human samples during the years 2008–2016 also revealed a high bio-load of 33.7% (Chaubey *et al*., 2017). The risk of MAP transmission exists even in pasteurized milk and its products owing to the ability of the organism to form clumps in milk that can lead to its survival even during pasteurization. Live bacilli have been also isolated from meat products and the environment, which illustrates the potential of MAP as a pathogen of public health concern. The organism is known to survive for 3 months in soft cheese and 10 months in hard cheese. MAP causes chronic inflammatory bowel disease in humans, akin to Jhone's disease in ruminants. Due importance must be given towards preventing the transmission of MAP from milk and its products, with research to ensure its zero-survival during pasteurization.

FOOD-BORNE ZOONOTIC VIRUSES

Virology research is rapidly expanding leading to discovery of new virulent viruses. The world has witnessed a series of outbreaks in the last decade due to consumption of food contaminated with emerging viruses like Nipah virus, avian influenza virus and SARS coronavirus. Although these outbreaks were mainly associated with a particular food habit, they have raised the concern about the possibility of transmission of emerging viruses to human via consumption of food contaminated during preparation, handling, slaughter, etc. Food-borne viruses are mainly transmitted via fecal-oral route through ingestion of contaminated food and water, and/or by person-to-person contact. Although the burden of food-borne viruses is largely unknown, a WHO (2015) estimate suggests that 15% of the food-borne related deaths due to diarrheal agents were caused by norovirus while 23.6% of food-borne related deaths were attributed to invasion of hepatitis A virus. Besides these, other viruses like enteroviruses, sapoviruses, rotaviruses, astroviruses, and adenoviruses have been also implicated in food- and/or water-borne illness. Several challenges including development of reliable diagnostics to detect viruses in food and generation of reliable surveillance data need to be addressed for devising adequate preventive and control measures.

Norovirus

Worldwide, norovirus (NoV) is the leading causative agent for acute gastroenteritis among children > 5 years of age who seek medical care. About 125 million cases of food-borne illness and 34,929 deaths due to NoV have been reported by WHO (2015). Recent improvements to diagnostic techniques have allowed researchers to describe the contribution of this highly infectious RNA virus to the burden of food-borne illness, particularly as a cause of numerous outbreaks of food-borne disease in community settings such as nursing homes, hospitals, the military, and cruise ships. The viruses are very diverse and are classified into seven genogroups of which only five are responsible for human gastroenteritis. Infective dose of this virus is as low as 10 organisms. In Southern India, of 1856 diarrheal episodes, 11.2% were associated with norovirus (Menon *et al*., 2016). NoV positivity varied between 6.3% to 12.6% in different cities of Western India with the predominance (96.6%) of genotype GII. First instance of inter-genogroup recombination has been reported from Kolkata, having polymerase sequence of GI and genotype 3 (GI.3), whereas the capsid sequence belonged to GII and genotype 4 (GII.4). Although no animal norovirus has been detected in human stool so far, few serological evidences hint towards possible transmission from animals to humans (Villabruna *et al*., 2019). It is presumed that some viruses that are categorized as human norovirus at present might have originated from animal source. Targeted surveillance, including samples of both humans and animals that are in close contact, is required to record a trans-species transmission event.

Hepatitis A (HAV) and hepatitis E virus (HEV)

HAV and HEV viruses are mainly transmitted via fecal-oral route. Zoonotic infections by HEV can occur via contact with infected animals or by consumption of contaminated food of animal origin. Most acute HEV infections in humans have been linked to consumption of contaminated pork or pig liver (Cossaboom *et al*., 2016). Both, HAV and HEV are highly endemic in India with reported sero-prevalence of 92.68% and 17.05%, respectively (Kotwal *et al*., 2014). Further, it was also observed that hand washing without soap, regular close contact with domestic animals, consumption of unpasteurized milk and regular consumption of food outside home are potential risk factors for HAV and HEV ($p < 0.05$). Status of HEV in pig in India is largely unknown because of limited studies conducted so far. Although their transmission through contact with infected animals have been demonstrated, the status of butchers and farmers still needs to be assessed in Indian context.

Rotavirus

Rotavirus is the leading cause of severe diarrhea in children in developed and developing countries including India. An estimated 47,100 rotavirus deaths occurred in India in 2013, which accounted for about 22% of the global deaths caused by this virus (Tate *et al*., 2016). In 2016, Government of India launched a vaccination program against rotavirus, but the data of diarrheal cases of post-vaccination are yet to be analyzed. This virus is highly contagious and mostly spreads through fecal-oral route. Although the burden of rotavirus illness has been extensively mapped, little attention has been paid to identify it other potential modes of transmission. The surveillance of circulating rotaviruses in the human population has revealed presence of uncommon strains that are usually found in domestic animals. Studies on unusual rotaviruses from livestock and companion animals are limited and the genomes of only a few of these strains have been analyzed so far. Surveillance for other rotavirus groups is also required, besides rotavirus A.

FOOD-BORNE PARASITES

Cryptosporidium, *Giardia, Cyclospora*, and *Toxoplasma* are the major foodborne parasitic protozoa worldwide. *Cryptosporidium* and *Giardia* are widespread in aquatic environment, and easily spread via contaminated drinking water. It has been reported that *Cryptosporidium* is responsible for 7% deaths in Indian children due to diarrhea (Troeger *et al*., 2017). In general, parasitic protozoa do not multiply in foods, but they can survive in food stored under moist, cool or damp conditions for months. *Toxoplasma gondii* is the potential food-borne pathogen, which can be transmitted through consumption of raw milk or under-cooked meat. This parasite is responsible for causing abortion in pregnant women and may also cause chorioretinitis and encephalitis. *Taenia solium* cysticercosis and trichinellosis are assumed to be fully foodborne, and mainly affect the people in developing countries of Africa, Asia and Latin America. It is second major cause of non-diarrheal food-borne deaths (WHO, 2015). Taeniasis and neurocysticercosis are very common in areas where animal husbandry practices are such that pigs and cattle come into contact with human faeces. The disease is prevalent throughout India, although its prevalence varies across the states (NHP, 2019). The National Institute of Mental Health and Neuro Sciences, Bangalore reported neurocysticercosis in 2% of unselected series of epilepsy patients. In a study emanated from New Delhi, neurocysticercosis accounted for 2.5% of all intracranial space occupying lesions. An unusual feature of the disease was its prevalence in more than 95% of Indian patients who are vegetarians due to transmission of *T. solium* eggs through contaminated water and salads. The exact burden due to parasitic contaminants in food is still largely unknown in India.

STATUS OF FOOD-BORNE DISEASES (FBDs) IN INDIA

The burden of food-borne diseases in Indian population is largely unknown. Most outbreaks of FBDs go unreported, un-recognized or un-investigated and may only be reported after major health damage has already been occurred. Recent estimates show that at least one of 12 people falls ill due to food-related infectious diseases in India. The number of FBDs is projected to grow by as much as 70% by 2030, largely driven by population growth and changing food consumption patterns (Kristkova *et al*., 2017). It is important to realise that the expected increase in FBDs might still be higher given the likely underestimation of the current burden. The analysis of data from Integrated Disease Surveillance Programme (IDSP) under National Health Mission for the period 2011 to 2015 revealed that food-borne outbreaks together with acute diarrheal diseases constitute nearly half of all reported outbreaks. Moreover, for the food-borne diseases, passive surveillance systems represent only the tip of the iceberg because most patients have mild symptoms of short duration and avoid visiting the health facility. Further, many of those who seek medical care may not have the laboratory test performed to determine a specific etiology. A review of the recorded FBD outbreaks in India from 1980 to 2016 revealed that *S. aureus*, *Vibrio* spp., *Salmonella* spp., *E. coli*, *Y. enterocolitica* and Norwalk-like virus are some important microbial pathogens responsible for food-borne illnesses (CD Alert, 2017). Different foods involved in food-borne outbreaks in India include milk and milk products *(curd, khoa, butter milk, sweets, kheer)*, meat, poultry, fish, fowl, seafood such as prawns, cooked and uncooked rice, samosa, tamarind, and cooked/ uncooked vegetables.

The total number of reported cases and deaths due to acute diarrheal diseases in India were 1,41,66,574 cases and 1555 deaths in 2016 and 12927212 cases and 1331 deaths in year 2017 (NHP, 2018). Community studies revealed that every child under 5 years of age had two or three episodes of diarrhea every year, and 400,000 to 500,000 children under 5 years died from it. Viral hepatitis was reported in about 12 cases per 100,000, although urban communities had as high as 100 episodes per 100,000 population. The estimated number of infected people may increase from 100 million people presently to 170 million by the year 2030, if the current scenario of food-borne illnesses is not alleviated (Kristkova *et al*., 2017),

STRATEGIES AND PREVENTIVE APPROACHES

In India, the implementation of standard operating procedures is completely lacking for supply of hygienic animal source foods at all the four stages i.e. production, processing, transport and marketing. Further, there is a gap in animal disease diagnostic facilities, food safety infrastructure and competent human resources. Consequently, farm to fork approach is required to ensure food safety, which involves series of steps to be taken by a multi-disciplinary team involving veterinarians, microbiologists, environmentalists, industry, and most importantly consumers. Since the FBZDs and their causative agents differ across regions, the preventive approach should be tailor-made to each region. The existing difference in the burden of food-borne diseases between low- and high-income regions clearly suggests that a major fraction of the current burden is still avoidable through implementation of general principles of food safety system. The enforcement of food safety standards based on risk assessment along with effective surveillance networks will aid in prevention of food-borne diseases to a large extent. The following strategies are suggested for effective prevention and control of FBZDs:

Strategy I - Surveillance and response

- Prioritization of important FBZDs on the basis of available information and interactions with policymakers, veterinarians, medical practioners, agricultural scientists, grass-root extension workers and civil society organisations belonging to different professional and social groups.
- Identification of network laboratories and working groups for each pathogen across the country.

- Use of validated diagnostics and common protocols for pathogen detection and identification.
- A statistical plan for sample collection from the entire value chain during surveillance.
- A protocol for information sharing and interactions among core groups, to consider reliability of the data based on their sources.
- Strengthen public health systems to support surveillance and to implement prevention and control programs.
- Improve ability to communicate electronically with state and local health departments.

Strategy II – Microbiological risk assessment and risk management

- Risk assessment studies need to be carried out for important food-borne zoonotic pathogens.
- Identification and implementation of different risk management options throughout the food chain from *farm to fork* for different food production systems.
- Establishing microbial standards, based on the MRA studies in the Indian context.

Strategy III - Applied research

- Development of reliable, rapid, simple and affordable diagnostic tests.
- Contrive rapid screening tests for detection of food intoxication, especially to test foods which are prepared and served in mass congregations.
- Explore alternatives to antimicrobial drugs.
- Genome analysis of food-borne pathogens to record interspecies transmission and to gain insights in the field of pathogen behaviour.
- Research on prevention and control of potential hazards throughout the food chain.

Strategy IV - Coordinated approach and awareness campaigns

- Establish regional labs where experts from human health, animal health and agricultural scientists work together to contain food-borne diseases with an integrated approach.
- Develop coordinated mechanisms to strengthen multi-sectoral cooperation.
- Awareness campaigns on zoonoses through interactions and training for professionals, high risk groups, common masses and people engaged in livestock industry.
- Instill true sense of sanitation and hygiene amongst various stakeholders through motivation, education and reward/recognition using mass media.
- Provide basic food safety education to ensure kitchen hygiene so as to avoid risky food practices.
- Advocacy on the role of local welfare bodies, municipal corporations and NGOs for prompt management and disposal of biohazard waste and garbage.

CONCLUSION AND RECOMMENDATIONS

Globally, food-borne diseases pose a significant threat to public health and socioeconomic development. However, information regarding magnitude of their burden due to specific pathogens is sketchy in India. On the other hand, precise information on the burden of food-borne zoonotic diseases is essentially required for taking suitable policy decisions regarding allocation of resources for food safety, control and intervention efforts. The prevention and control measures should be initiated by the veterinarians stating from primary production through Good Animal Husbandry Practices (GAHP) and biosecurity measures. Further, Good Manufacturing Practices (GMP) and Good Hygienic Practices (GHP) and implementation of HACCP should be followed at production and processing levels as to reduce the burden of food-borne diseases. There is an urgent need for prudent use of antibiotics in both human and animals as to mitigate the rising antimicrobial resistance. The '*One Health*' approach may not only improve the understanding of epidemiological nature of diseases, but also aid in effective implementation of control measures. It is increasingly necessary to consider holistically all aspects of food-borne diseases in the *One Health* framework.

RECOMMENDATIONS/ ACTIONABLE POINTS

- Formulate a collaborative, long-term, multi-sectoral 'Network Programme on Food-borne Diseases' with the mandate of conducting surveillance studies on food-borne zoonotic diseases followed by risk assessment studies for most prevalent/important pathogens.
- Formation of 'Rapid Response Teams' comprising multi-subject specialists for investigation of food-borne disease outbreaks.
- Up-gradation and expansion of diagnostic laboratories in a network mode on priority basis.
- Inclusion of veterinary public health specialists in all the Integrated Disease Surveillance Programme (IDSP) laboratories.
- Creation of a digital database on the lines of 'FoodNet' of Centres for Disease Control and Prevention (CDC), USA.
- Integrate food safety into the food security and nutritional policies and programs.
- Incorporate zoonoses including food-borne infections and emerging infectious diseases in the national health policy.
- Establishment of modern hygienic slaughter sources at least one at the block level.
- Mandatory training of butchers on hygienic slaughter practices and making it compulsory that only those personnel who have completed this training can do dressing.
- Training of street food vendors in the basics of hygiene and food safety, and issue of certificates so as to improve consumer confidence.
- Establishment of small animal source food processing units in rural areas that minimize spoilage and provide much needed employment to rural people.
- Aspects of food-borne zoonotic disease and food safety may be made part of the course curriculum at school and for undergraduate level for students of home science and hospitality management.

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