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REVIEW ARTICLE

Microbiological food safety: a dilemma of developing societies

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Abstract

Current food safety issues are deleteriously reshaping the life style of the population in the developing world. Socioeconomic status of the population in poorer economies is one of the major determinants to delineate the availability of safe food to the vulnerable population. Assessment of the prevalence of foodborne illness in developing world is the most neglected area to control disease. Botulism, Shigellosis, Campylobacteriosis, *Escherichia coli* infection, *Staphylococcus aureus* infection, Salmonellosis, Listeriosis and Cholerae are extensively prevalent and pose a major threat to human health in underdeveloped communities. The existing food safety status of many African, South Asian, Central, and South American developing countries is distressing therefore; it seems much timely to highlight the areas for the improvement to ensure the supply of safe food to the population in these regions. Extensive literature search at PubMed, Science Direct and Medline was carried out during the current year to catch on relevant data from 1976 to date, using selective terms like food safety, South East Asia, Africa, Central and South America, and foodborne illness etc. Efforts were made to restrict the search to low income countries of these regions with reference to specific foodborne pathogens. This report briefly discusses the present food safety situation in these developing countries and associated consequences as prime issues, suggesting foodborne illness to be the most distressing threat for human health and economic growth.

Keywords

Botulism, Campylobacteriosis, *Escherichia coli* infection, *Staphylococcus aureus* infection, Salmonellosis

History

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Introduction

Food safety has emerged as a global challenge and most of the developing countries are the victims of the devastating perils of foodborne illness. Since, microbes are developing resistance and are able to survive many food production and processing operations thus they pose a potential threat to human health and are regarded as the major sources of foodborne illness. Food safety is well recognized as a primary indicator of economic growth in the developing world therefore, a wave of realization has spurred both at public and government levels for safe food supply. However, the situation still remains much depressing in the developing countries. International organizations are inclined to help developing nations combat food safety issues; hence, numerous NGOs and local consumer groups are teeming in these states to work for food safety.

In spite of the recent advancement in the domain of Food Science and Technology and a growing concern raised by various international working groups on food safety, prevalence of foodborne illness still remains a substantial cause of morbidity and preventable death. Developed economies are no exception to the risk of foodborne illness as one-third of the population undergoes this type of illness annually. Moreover, outbreaks in the United States, Australia, Germany, and India are clear indicative of the severity of the problem because 30% of the population in these countries suffered from foodborne illness each year (Tauxe, 1997), and 9.4 million in the United Kingdom (Walker et al., 2003). Similarly, 1200 million cases of diarrheal illness in the US are reported annually involving *E. coli*, *Salmonella* spp., *Shigella* spp., *Cyclospora* spp., *Cryptosporidium* spp., *Campylobacter jejuni*, *Clostridium difficile*, and other enteric viruses (Guerrant et al., 2001).

Prevalence of foodborne illness though not well documented on account of poor monitoring and surveillance is recognized as a potential determinant for rapidly declining economic growth in underdeveloped countries. Paucity of literature and statistical data to estimate the economic loss associated with foodborne illness in developing regions is existent and this scarcity of information implies poor surveillance systems that hinder the nations to achieve higher food safety standards. Experience shows that infection control requires plenty of expertise in related fields such as food microbiology, chemistry, and epidemiology etc. Possibly, these skills are available in developing countries but there is no systematic approach available so far to undermine the fast growing incidence of foodborne illness. For example, no significant foodborne illness outbreak has been documented systematically in South Asian or African developing

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economies so far, though very small epidemiological studies were carried out in the past which undeniably could not suffice to estimate the real economic loss. Most of the countries of developing world have no precise foodborne illness monitoring and surveillance system to compute economic losses incurred as non-productivity, cost of medication and Disability Adjusted Life Years (DALYs).

Extent of mortality among children in developing countries due to diarrhea estimates 1.8 million deaths annually, suggesting a massive economic burden as a result of foodborne illness (WHO, 2005). Economic constraints, political instability, nonexistence of infrastructure and nonadherence with the existing food laws are the significant markers of unsafe food supply. This is further intensified by scantiness of public awareness on health and economic consequences of foodborne illness, illiteracy, poverty, malpractices, and corruption and on top of that legislation that needs to be compatible with the local beliefs and principals in the low income countries. It is particularly important to understand what economic consequences are ahead if corrective measures are not taken (Henson, 2003). Hardly any developing country would have acquired precise estimates of the burden of foodborne disease because numerous instrumental reasons deter the correct estimation, for example a majority of the cases especially for diarrheal illness are not reported (Flint et al., 2005).

Extensive body of literature confirms number of foodborne disease outbreaks worldwide. Several recent foodborne disease outbreaks are reported in the United States where hygiene and sanitation is much better and the governmental agencies like local health departments, Center for Disease Control and Prevention (CDC), Federal Regulatory Agencies, Food and Drug Administration (FDA), USDA's Food Safety and Inspection Service (FSIS), and the Environmental Protection Agency (EPA) are efficiently functioning to control foodborne illness. Twenty nine people died in Colorado within a time span of 3 months only i.e. July-September owing to the consumption of Del Monte cantaloupe infected with *Salmonella* spp. (CDC, 2011).

Foodborne illness in the US caused by *Campylobacter*, non-typhi *Salmonella* spp., *E. coli* O157, *E. coli* non-O157 shiga toxin *E. coli* (STEC) and *Listeria monocytogenes* resulted in a loss of $6.9 billion in terms of medical costs, productivity losses and value of premature deaths in 2000. Correspondingly, an expected loss of $7.2 million is endured for each death of a child dying before the first birthday comparing with one dying at an age of 85 or more (Henson, 2003). These statistics might be virtuously exploited to make a comparison of the economic losses born by the US government with all those services and resources available which practically do not exist in the developing countries of South Asia, Africa, and Central and South America. Therefore, understanding the emerging food safety challenge is rather demanding and requires public health workers and all stakeholders to strive with improved methods to overcome foodborne illness in developing countries (WHO, 2005).

The present review is an attempt to assimilate facts and figures with particular emphasis on South Asian, Central and South American and African developing countries to assist governments to develop a food safety roadmap to combat foodborne illness.

Bacterial agents and foodborne illness

Botulism

Four main species of C*lostridium* produce disease in humans i.e. *C. botulinum*, *C. difficile*, *C. perfringens*, and *C. tetani*. Foodborne botulism is caused by ingesting minimally processed foods such as canned foods especially prepared at home because heat resistant spores survive in these erroneously handled foods. A potent neurotoxin, found in seven different forms is produced during the growth of *C. botulinum* resulting in severe neuroparalytic syndrome (Arnon et al., 2001; Skarin et al., 2011). Paralysis begins with blocking motor nerve terminals at the myoneural junction and the resulting conditions lead to death. Nevertheless, the illness is rare and uncommon because the organism thrives in specific conditions of temperature, oxygen, acidity, and water activity. These conditions generally do not exist simultaneously in a food system to favor the bacterial growth but usually involve health risks with higher mortality rate (Cengiz et al., 2006; Dobbs & Austin 1997).

Shigellosis

Shigellosis, primarily a disease of children and young adults, kills 600,000 children under 5 years of age annually worldwide. The symptoms of shigellosis include fever, abdominal cramps and tenesmus coupled with loose stools containing blood and mucus, eventually resulting in hemolytic uraemic syndrome. *S. sonnei*, *S. boydii*, *S. flexneri*, and *S. dysenteriae* are the four serogroups mostly responsible for shigellosis. Thus, shigellosis is considered a major public health problem worldwide and is recognized as a global problem (Frost et al., 1981; Hossain et al., 1990; Rosenberg et al., 1976; Sur et al., 2004).

Campylobacteriosis

Campylobacter jejuni is reported as the major cause of gastroenteritis worldwide. Developing countries however, are more prone to campylobacteriosis owing to mishandling of foods, unhygienic water supply, and poor sanitary conditions. Campylobacteriosis is aggravated due to the lack of treatment facilities and health care services in developing countries subsequently distressing the impoverished people. The victims generally do not have access to safe drinking water and live in proper sanitary conditions (Coker et al., 2002; Oberhelman & Taylor, 1999; Soofi et al., 2011; WHO, 2002). Development of post infection neurological complications due to *Campylobacter* is another intimidating feature of this organism. Patients suffering from *Campylobacter enteritis* are at increased risk of developing Gullien Barre syndrome (GBS), a serious life-threatening neurological disease (Tam et al., 2007).

Escherichia coli infection

E. coli is mainly found in the gut of humans, mammals, and birds and infection is considered as a reliable marker of fecal contamination. Enteropathogenic and/or toxigenic microorganisms of intestinal tract of mammalian species are well represented by the presence of *E. coli.* Majority of the *E. coli* strains may not be hazardous however,a few of them

cause severe intestinal disease in man. Classification of harmful *E. coli* is generally made on the basis of the production of virulence factors and clinical manifestations (Kaper et al., 2004).

Staphylococcus aureus infection

Staphylococcus aureus, a most frequent pathogen, is known to be a major cause of foodborne illness (gastroenteritis). Food poisoning occurs on absorption of staphylococcal enterotoxins and is indicated as abdominal cramps, nausea, vomiting following diarrhea (Le Loir et al., 2003). *S aureus* is an inhabitant of nostrils, skin and hair of warm-blooded animals and is carried by 30–50% of the human population. The microorganism is capable of growing under a wide range of temperature i.e. 7–48.5°C (Schmitt et al., 1990).

Salmonellosis

Salmonella spp., a group of Gram-negative enteric bacteria, is important human food poisoning pathogens in the developed and developing world. *Salmonella* mainly reside in chicken products however, a wide range of foods have been identified for being contaminated with these bacteria which subsequently transmit disease in humans particularly children (Flor et al., 2011; Rajashekara et al., 2000). Last decade witnessed increased worldwide incidence of gastrointestinal infections by *Salmonella*, transmitted through infected poultry flocks, meat, and eggs (Holt et al., 1994). *S. enteritidis* is known to be the most prevalent and the major cause of human salmonellosis. Approximately, 380 salmonellosis outbreaks resulted in around fifty deaths in United States from 1985 to 1991 (Mishu et al., 1994). Salmonellosis, as a major public health problem, is shown to severely impact socioeconomic status of the sufferers and is also a primary concern for developing countries (Hassan et al., 2008; Razzaque et al., 2009) (Table 1).

S. typhi and *S. paratyphi,* are much more dangerous in developing societies. The bacteria stay within human and are transmitted through consumption of foods infected with patient's and carrier's feces. Street vended cultural foods, a commonplace in developing economies, are considered to be the route of *S. paratyphi* transmission. *S. typhi* and *S. paratyphi,* though less prevalent, contributed 50% of salmonellosis in the last decade among South-Central Asia and South-East Asian countries (Crump & Mintz, 2010; Fangtham & Wilde, 2008; Hardy, 2004; Linam & Gerber, 2007).

Listeriosis

Listeria monocytogene, a potentially opportunistic foodborne pathogen, is responsible for infection in population especially with immunosuppression. High mortality rate is recorded for this pathogen among neonates and adults. Although, infection caused by *L. monocytogene* is rare, even then numerous outbreaks resulting from this pathogen are recorded in the history involving milk, cheese, vegetables, and meat products as the vehicles of transmission. These food commodities are generally considered a source of Listeriosis in 99% cases. Septicemia, meningitis, and loss of fetus are common outcomes of *L. monocytogene* infection and mortality rate due to Listeriosis accounts for 25% (Slutsker et al., 2000). The organism is unique for its ability to grow at refrigeration temperatures and at a wide range of pH thus poses a threat in food industries producing products with extended shelf life and kept at low temperature (Moretro & Langsrud, 2004; WHO, 1988)

Vibrio cholerae infection

According to World Health Organization, global prevalence of cholera has amplified resulting in 100,000–130,000 deaths and covering a dominating part from the developing world in

Table 1. Annual burden of diarrhea due to ETEC among children aged up to 4 years in different settings in the developing world.

	Age group		
Setting	0–11 month(s)	1–4 year(s)	Total 0–4 year(s)
Domicile			
Total no. of diarrheal cases	429,975,000	868,455,000	1,298,430,000
% of ETEC episodes	14.5	22.5	19.8
No. of diarrheal cases due to ETEC	62,346,375	195,402,380	257,748,755
Outpatient			
Total no. of diarrheal cases	50,212,500	74,655,000	124,867,500
% of ETEC episodes	10.9	19.7*	16.2
No. of diarrheal cases due to ETEC	5,473,162	14,707,035	20,180,197
Hospital			
Total no. of diarrheal cases	7,312,500	1,890,000	9,202,500
% of ETEC episodes	13.7*	12.9	13.5
No. of diarrheal cases due to ETEC	1,001,812	243,810	1,245,622
All settings			
Total no. of diarrheal cases	487,500,000	945,000,000	1,432,500,000
% of ETEC episodes	14.1	22.2	19.4
No. of diarrheal cases due to ETEC	68,821,349	210,353,225	279,174,574
No. of diarrheal episodes due to ETEC/person/year	0.54	0.47	ND

*ETEC was not significantly more often isolated from individuals with diarrhea than from controls.
ETEC, enterotoxigenic *Escherichia coli*; ND, not done.
Source: Wennerås and Erling (2004).

2010 (Reidl & Klose, 2002; WHO, 2010). Cholerae has been identified both epidemic and endemic in many parts of the world especially the countries of the third world where a majority of the cases are not reported. Therefore, it is hard to figure out the correct incidence rate of cholerae in the developing world (Sack et al., 2004).

Food safety in South Asian developing countries

Food processing and marketing in South Asian countries undergo several stages involving quite a large number of handlers in the market chain. Moreover, modern technologies for processing and storage are lacking and the awareness on food safety for human health among the stakeholders is still missing. Amongst several potential determinants, absence of food safety management systems, good agricultural practices (GAP) and good manufacturing practices (GMP) especially at small scale production and processing has been a known reason for the development of foodborne illness in this region. The street vending of a wide range of food products in most of the resource constrained South Asian countries magnifies the issue manifold and calls for serious efforts to tackle the unique challenge of food safety.

The situation of botulism outbreaks in different parts of the world is sufficiently terrifying. Magnitude of the global prevalence of foodborne outbreaks of botulism is increasing especially in the developing economies owing to changing life styles and poor sanitation and hygiene (Rebagliati et al., 2009). Ecological studies show massive botulism outbreaks associated with the consumption of inappropriately prepared indigenous cultural foods. Botulism cases reported in the last few decades e.g. 33 cases with three deaths between 1989 and 2005 in United Kingdom (McLauchlin et al., 2006), 160 foodborne botulism outbreaks between 1990 and 2000 in United States (Sobel et al., 2004) and a total of 91 botulism cases in Alaska between 1990 and 2000 (Chiou et al., 2002), clearly indicate that the developed nations with improved delivery of health services and a substantial level of food safety surveillance system are no exception to this issue.

Various reports on the prevalence of botulism in India (Agarwal et al., 2004; Dhaked et al., 2002; Lalitha & Gopakumar, 2000), implicating several communities consuming canned meat products and fish, demonstrated consequential dominance of the disease in the region. Another massive botulism outbreak afflicting 310 students of a residential school in rural Gujrat, India for consuming *ladoo* (a local sweet product), curd, buttermilk, *sevu* (crisp made of gram flour), resulted in 14 deaths (Chaudhry et al., 1998).

A total of 209 people in a village in Thailand suffered from ingestion of *botulinum* toxin through contaminated home-canned bamboo shoots in 2006. Among these, 134 persons were seriously distressed and 42 were placed on mechanical ventilation. That episode of food poisoning was considered to be a massive outbreak of botulism in Northern Thailand and serious concern was raised on international capacity to urgently address the issue (Ungchusak et al., 2007). Similarly, occurrence of botulism in China resulted in 421 deaths through 1989 from 15 provinces reporting 2861 cases involved in 745 outbreaks and 986 outbreaks of botulism were reported in Xinjiang, province of China during 1958–1983 sickening 4,377 people of which 548 died (Gao et al., 1990; Shih & Chao, 1986).

Epidemiological studies demonstrated botulism as a potential human health risk in various parts of Iran. Likewise, occurrence of botulism was reported in the northern province of Iran in 1997 affecting 27 patients with one death (Aminzadeh et al., 2007; Barari & Kalantar, 2010; Vahdani et al., 2006).

No significant study on outbreaks of botulism has been documented in Bangladesh so far. Unidentified and unreported cases are likely to go unnoticed owing to the absence of any surveillance and reporting mechanism. Data pertaining to *C. botulinum* incidences in Pakistan are also scant; the cases relating to botulinum outbreaks are hardly diagnosed and recorded.

Children under five are the most vulnerable population fraction severely affected by shigellosis in the developing countries. A substantial number of reports from developing countries including, Pakistan, Bangladesh, Sri Lanka, Maldives, Nepal, Bhutan, Thailand and India evidently indicate shigellosis as the most perilous infection resulting in high morbidity and mortality throughout the year. The high prevalence of shigellosis in developing countries is associated with inappropriate sanitation, hygiene, hot, humid and rainy season and particularly flies ubiquitous in these regions (Agtini et al., 2005; Levine & Levine, 1991). Shigellosis affects around 163.2 million people in developing countries each year (Kotloff et al., 1999; Sur et al., 2004; WHO, 2005). Other estimates show 414,000 deaths, occurring due to shigellosis in Asia (Legros, 2004) and 1.1 million deaths in developing countries (Niyogi, 2005).

Despite the fact that higher standards of sanitation and hygiene are in place in Thailand, 19–37% children under various age groups during 1993–2006 were affected by shigellosis. Population in Bangkok was mainly affected by *S. flexneri* while *S. sonnei* clustered around in southern Thailand in 2006 (Bangtrakulnonth et al., 2008) (Table 2).

Shigellosis appears to be widely pervasive in Indian subcontinent with *S. flexneri* to be a common serogroup. Bangladesh is one of the most affected regions in South Asia with regard to foodborne illness. Poverty and natural calamities specifically cyclones are a commonplace and badly affect the socioeconomic status of the population. Incidence of foodborne illness is a usual event in Bangladesh. Diarrheal episodes in Bangladesh are at the rise particularly during the rainy season (Lobitz et al., 2000; Sack et al., 2004).

Prevalence of shigellosis in community settings of Pakistan is alarming and has shown to deleteriously impact the health and wellbeing of the masses. Estimates show 576 000 deaths among children per year in northern regions of Pakistan (Bennish, 1991; Soofi et al., 2011; WHO, 1988).

In addition to several other contributory factors, rational reduction in shigellosis incidences in underdeveloped countries may be achieved through the improvement of living standards, developing awareness on the complications of foodborne illness and specifically supplying safe water. Moreover, availability of diagnostic facilities at the onset of disease, surveillance and monitoring, implementation of health care policies, awareness on the benefits of hand washing practices to stop transmission of disease from one

Table 2. Study population, disease episodes, and shigellosis incidence at six study sites (all ages).

Characteristic	China Zhengding	Thailand Saraburi	Indonesia North Jakarta	Vietnam Nha Trang	Pakistan Karachi	Bangladesh Dhaka	Total
Total population	75,630	80,141	160,257	200,410	59,584	29,309	605,331
Surveillance period	1/2002–12/2002	5/2000–4/2003	8/2001–7/2003	1/2001–12/2003	1/2002–12/2003	6/2002–5/2004	–
Presentations	11,342	8,612	16,872	11,419	10,540	3,481	62,266
DE included in analysis	10,104	6,536	16,225	10,258	10,371	3,464	56,958
(% of presentations)[a]	–89%	–76%	–96%	–90%	–98%	–100%	–91%
DE Shigella spp. isolated	330	146	1,203	390	394	464	2,927
(% of included episodes)	–3%	–2%	–7%	–4%	–4%	–13%	–5%
S. flexneri episodes (% of SE)	305 (92%)	22 (15%)	866 (72%)	282 (72%)	242 (62%)	259 (58%)	1,976 (68%)
S. sonnei episodes (% of SE)	25 (8%)	124(85%)	277 (23%)	101 (26%)	72 (18%)	53 (10%)	652 (22%)
S. dysenteriae episodes (% of SE)	0	0	21(2%)	6(2%)	37(9%)	46(9%)	110 (4%)
S. boydii episodes (% of SE)	0	0	39(3%)	1(0%)	43 (11%)	106 (23%)	189 (6%)
SE hospitalized (% of SE)	5 (2%)	2 (1%)	76 (6%)	71(18%)	0 (0%)	NA	154 (6%)
IR diarrhea, per 100 per year	13.4	2.7	5.1	1.7	8.7	5.9	4
IR shigellosis, per 1,000 per year	4.4	0.6	3.8	0.6	3.3	7.9	2.1

DE, diarrhea episodes; IR, incidence rate; NA, not available; SE, Shigellosis episodes.
[a]To be included in the analysis patients had to have diarrhea, defined as three or more loose bowel movements within 1 day or one or more loose bowel movements with visible blood, and to consent to participate in the study.
Source: von Seidlein et al. (2006)

person to other and introduction of an effective vaccine against *Shigella* seem to be the effective approaches to reduce shigellosis in the region (Bhattacharya & Sur, 2003; Dutta et al., 2003; Kotloff et al., 1999; Sur et al., 2004). Albeit, achieving the goal to eliminate or reduce shigellosis in developing countries is highly demanding, however concerted efforts need to be continued by international agencies and local health care institutions to address the issue.

Higher prevalence of Campylobacteriosis is confirmed in Thailand which is predominantly ascribed to drug resistance. Similarly, Bangladesh, India and Pakistan are considered to be the regions in South Asia with relatively higher frequency of *Campylobacter* infections. *C. jejuni* is the most common milk borne pathogen known to be prevalent in Pakistan, India and Bangladesh and implicates a significant portion of the population in various community settings (Haq & Rahman, 1991; Serichantalergs et al., 2007). Like other foodborne pathogens, drug resistance of *Campylobacter* is an important cause of increased prevalence of Campylobacteriosis. Imperfect and unsatisfactory surveillance and monitoring system in developing countries are some of the potential determinants, leading to failure in controlling Campylobacteriosis (Gibreel & Taylor, 2006).

Enterotoxigenic *E. coli* (ETEC) are known to be the most common cause of diarrhea, affecting infants, children and adolescents in countries with limited resources. Morbidity rate due to ETEC in five developing countries demonstrated a continual trend in diarrheal cases during the first three years of life (Huilan et al., 1991). Breast feeding is reported to be a preventive measure for diarrhea among infants in Bangladesh (Merson et al., 1980) and Mexico (Spencer et al., 1980), however the control did not last over the first 2 to 3 years of life (Kotloff et al., 1999). Likewise, milk based indigenous sweet products were found to be a substantial source of *E.coli* contamination causing infection in India as *E. coli* was frequently isolated from milk products like *Mawa, Gulabjamun, Rasgulla* (indigenous sweet products), cream, yoghurt, cheese and butter (Kumar & Prasad, 2010) (Table 3).

World has seen a considerable vigilance among countries of the European Union after the deadly outbreak of shiga toxin-producing enterohaemorrhagic *E coli* O104:H4 in Northern Germany which resulted in numerous deaths and infected over 1,700 people (Greinacher et al., 2011). Developing countries including India, Pakistan and Bangladesh seem much cautious about the deadly strain of shiga toxin-producing *E coli*. Haemolytic uremic syndrome (HUS) causing kidney failure is the common outcome of the infection by these bacteria (Sinha, 2011).

Staphylococcus aureus food poisoning is less recognized in developing countries as compared to the developed nations where it is prioritized as a public-health agenda. South Asian countries are more likely to suffer from staphylococcal food poisoning for being resource-limited and poorer economies (Nickerson et al., 2009).

Staphylococcal food poisoning is more prevalent among infants in different community reservoirs in South Asian countries. The mortality rate due to this type of food infection is much higher i.e. ~50%. Methicillin-resistant *S. aureus* is a threat for being highly prevalent in South Asian developing countries (Hiramatsu et al., 1997; Nickerson et al., 2006).

Epidemiological surveillance and studies from Asian countries illustrated an annual incidence of *S. typhi* prevalence to be much higher in Pakistan (451.7 cases/100,000) as compared to neighboring countries like India (214.2 cases/100,000), Vietnam (21.3 cases/100,000), and China (15.3 cases/100,000) (Ochiai et al., 2008; 2010). A few reports from Pakistan indicate *S. enteritidis* to be more devastating for the population at risk. Out of a total of 58 isolates of *Salmonella* spp., from poultry eggs, poultry meat, poultry droppings and stool from human diarrhea cases in Faisalabad city of Pakistan, 75.86% of the isolates were *S. enteritidis* (Akhtar et al., 2010).

Earlier, listeriosis was thought to occur sporadically in Asia but it is currently much widespread across the region. These sporadic infections in subcontinent are normally attributed to raw and heated food samples, milk, and

Table 3. Estimated incidence of foodborne Salmonellosis in some developing countries.

Product	Egypt	Brazil	Zimbabwe	India
Poultry (Raw)	14,800	728,000	49,300	28,300
Eggs (Raw)	572,000	3,270,000	53,100	2,830,000
Beef (Raw)	0	256,000	13,900	405,000
Pork (Raw)	201	129,000	0	584,000
Milk & dairy products (Ready-to-eat)	5,230	51,000	1,200	241,000
Fish & seafood (Ready-to-eat)	34,200	135,000	2,030	1,410,000
Fruit & vegetables (Ready-to-eat)	332	1,240	46	12,600
Total	627,000	4,570,000	120,000	5,510,000

Source: WHO (2002).

vegetables. Human listeriosis appears among individuals having suppressed T-cell immunity (Farber & Peterkin, 1991; Kohler et al., 1991). Pregnant women and neonates generally become a target of listeriosis (Holbach et al., 1988; Zaidman et al., 1990).

Sanitation and hygienic conditions in Indian subcontinent are life threatening and are likely to jeopardize the entire food supply chain. Reported cases of listeriosis confirmed 17.5% food samples to be contaminated in Mangalore, South India, indicating the magnitude of the prevalence of the disease in the region. Seafood, beef, raw milk, vegetables were found to be implicated with *Listeria* spp. Similarly, several other studies demonstrated the presence of *Listeria* spp., in a variety of foods tested in India such as meat and their products. *L. innocua*, *L. murrayi*, *L. seeligeri*, and *L. ivanovii* were identified as the principle strains involved (Kamat & Nair, 2007).

Cholerae epidemics in third world countries are generally linked with unsanitary conditions that often exist in this region. South Asian countries also witnessed many cholerae outbreaks in the documented history and in addition to six pandemics of *V. cholerae*, El Tor biotype was found to be responsible for seventh cholerae pandemic (Sack et al., 2004). Similarly, newly described non-O1 serogroup of *V. cholerae* caused unusual cholerae outbreaks in India and Bangladesh in 1992 (Cholera Working Group, 1993; Ramamurthy et al., 1993).*V. cholerae* serogroup O139 was reported in Karachi, Pakistan (Fisher-Hoch et al., 1993). Among 689 *V. cholerae* isolates from a tertiary care hospital in Karachi, 144 (21%) were detected to be of serogroup O139 in 2001 (Jabeen & Hasan, 2003).

V. cholerae O139 is shown to be a potential cause of major epidemic in populations with compromised immune systems. *V. cholerae* non-O1 serogroups were also identified as a cause of diarrhea epidemics in 1992. Larger part of India and Bangladesh was inflicted with *V. cholerae* O139 outbreak which reached Pakistan in a few months in 1993 (Fisher-Hoch et al., 1993). Similarly, two consecutive *V. cholerae* epidemics were observed in a peri-urban village in Karachi, Pakistan in 2006 resulting in high morbidity (Siddiqui et al., 2006) (Table 4).

Food safety in Central and South American developing countries

Recent episodes of foodborne illness and substandard food safety status in countries of Latin America necessitate improved hygiene, sanitation, and awareness for the availability of safe food. According to an estimate, 6000 outbreaks of a number of different foodborne diseases were reported in Latin America and the Caribbean between 1993 and 2002. The economic loss incurred through these outbreaks and several single cases of foodborne disease is enormous (Anon, 2012).

Microbiological contamination of a plenty of foods has been identified as a potential cause of foodborne illness in Latin American countries e.g. 90 samples of ready-to-eat foods were evaluated to ascertain their microbiological safety in Costa Rica, taking *Salmonella*, *L. monocytogenes*, *C. perfringens*, *C. botulinum*, and *B. cereus* as indicators of quality and safety of these foods. High fecal contamination in these foods explicitly suggested application of GMP, better sanitation and hygiene with a focus on critical control points (Rodríguez-Cavallini et al., 2010). Another study confirmed the prevalence of *L. monocytogenes* in Costa Rican soft cheese samples, an identified source of Listeriosis in the region and is considered a potential source of pathogenic strains for humans (Chaves & Arias 2009).*C. perfringens* type A food poisoning is the third most commonly reported foodborne illness in the United States (McClane, 2007; Olsen et al., 2000). Costa Rican foods, particularly meat is prone to contamination by this microorganism. Rodríguez et al. (2002) evaluated raw and cooked meats for *C. perfringens* in relation to environment in Costa Rica. The results showed that 88% of the soil samples collected from the slaughter house environment, were contaminated with *C. perfringens*. Bacterial isolates were also evaluated for enterotoxin production and the researchers suggested to adopt sanitation and hygiene to prevent the risk of foodborne intoxication by these bacteria.

Guatemala's food export was banned for two outbreaks occurring in 1996 and 1997 which sickened the people on consuming Guatemalan raspberries contaminated with a parasite called cyclospora. Florida outbreak of typhoid fever inflicting 16 people in 1998–1999 was traced to the consumption of fruit shakes prepared by using frozen mamey, contaminated with fecal coliforms and exported from Guatemala and Honduras (Katz et al., 2002). Similarly, the documented epidemic in humans with *S. enteritidis* in Uruguay demonstrated that the organism was associated with foodborne illness in Central American developing countries. The microorganism is particularly prevalent in inappropriately handled poultry products. A nationwide survey to analyze sera from 5,751 birds and 12,400 eggs in Guatemala concluded 24.4% and 6.3% of the birds infected with *Salmonella* group O:9 and *S. enteritidis*, respectively (Betancor et al., 2010).

The reported shiga toxin-producing *E. coli* (STEC) outbreak in July 2011 in Germany, distressing 852 patients with HUS and 32 deaths associated with HUS has alerted the international community to exercise very special cautions to avoid such incidence. STEC proliferate through cattle's feces and hides in the slaughterhouses. A study evaluated the

Table 4. Comparison of demographic and clinical characteristics of 29 Vibrio cholerae O139 patients in 2002 and Vibrio cholerae O1 patients in 2003 in Rehri Goth, Pakistan.

Characteristic	*V. cholera* O139 [*n* (%)]	*V. cholera* O1 [*n* (%)]	*p* value	OR (95% CI)[b]
Under 2 years old	6 (21)	18 (49)	0.02	—
Male	16 (55)	23 (62)	0.16	—
Sick for >2 days prior to presentation	3 (10)	10 (27)	0.09	0.5 (0.1—2.0)
Dysentery	2 (7)	2 (5)	0.80	0.8 (0.1—6.3)
Watery diarrhea	16 (55)	31(84)	0.01	0.2 (0.1—0.6)
Increased thirst	26 (90)	21(57)	0.00	5.9 (1.5—23)
Dehydrated	2 (7)	5 (14)	0.38	0.5 (0.1—2.9)
Abdominal pain	2 (7)	0 (0)	0.11	—
Vomiting	5 (17)	8 (22)	0.66	1.0 (0.3—3.7)
History of fever	16 (55)	2 (5)	0.00	38 (6.9—208)
Fever (>37.5°C) on presentation	11 (38)	1(3)	0.00	23 (2.7—195)
Intravenous fluids required	4 (14)	9 (24)	0.28	0.4 (0.1—1.7)

[a]Case report forms were completed for 29 of 30 patients in the 2002 outbreak. [b]Odds ratio (OR) and 95% CI adjusted for age. Source: Siddiqui et al. (2006).

carcasses for STEC in Argentina and reported 12.34% and 18.64% of STEC at the slaughter house and sanitary control cabin. Argentina has the highest incidence of HUS in the world therefore, an extensive survey to assess non-O157 STEC contamination in carcasses and feces of bovines from nine beef abattoirs in Argentina was carried out. The results reported that 4.8% (39 of 811) of the bovine carcasses were found contaminated with non-O157 STEC strains. The outcome of the survey revealed that these levels of contamination are a public health issues and need immediate attention (Masana et al., 2011; Etcheverría et al., 2010).

Outbreaks of botulism reported in Argentina since 1992 are the corollary of inappropriate processing of meats and vegetables and other homemade foods. Moreover, ham, red, and green chili peppers have also been implicated in such outbreaks (Rebagliati et al., 2009). *Yersinia enterocolitica*, a species of Gram-negative coccobacillus-shaped bacterium is able to cause acute gastroenteritis in humans. The prevalence of *Y. enterocolitica* in meat products has also been widely reported (Estrada et al., 2012; Siriken, 2004; Laganà et al., 2008) in the literature.

An attempt to improve food safety conditions and health system as a part of Brazilian National Program, was made to monitor antibacterial resistance in chicken in the year 2004–2006, covering 15 Brazilian cities in the five geographic regions, *Salmonella* spp., were isolated and serotyping was carried out and *Salmonella* strains were tested against 18 antimicrobials. The results presented *S. enteritidis*, to be the most prevalent strain (48.8%) followed by *S. infantis* (7.6%). The researchers reported high multidrug-resistant among these strains (Medeiros et al., 2011).

In Chile, a total of 171 samples of salmon, shrimp, and tilapia imported from 12 countries in three retail stores in Baton Rouge, LA were analyzed for *Campylobacter*, *E. coli*, *Listeria*, *Salmonella*, *Shigella*, and *Vibrio*. The highest prevalence of *L.monocytogenes* (9.4%) was noticed in this study. Intermediate bacterial resistance against ampicillin was seen for *V. parahaemolyticus.* The results were suggestive of the potential food safety hazards associated with imported seafood in Chile. Besides, frequency of diarrhoeal episodes was attributed to seafood consumption (shellfish) and prevalence of *V. parahaemolyticus* in the environment of Puerto Montt, Chile was also reported (Wang et al., 2011). Similarly, *Campylobacter* contamination of poultry slaughter houses indicated high counts in Chile attributing the contamination with limited effect of chilling process and improper cooking practices (Figueroa et al., 2009; Fuenzalida et al., 2006).

Around 9000 people died in 2 years and 1 million were affected by epidemic of cholerae in Latin America during 1991–1993. Drinking water was linked as the cause of this outbreak in Peru. Moreover, unwashed fruits and vegetables in addition to the consumption of street vended foods were associated with Cholerae outbreak. This epidemic, crossing the Peruvian borders reached Ecuador, then Colombia and afflicted millions of people in the adjoining states. The author concluded that state of food safety is distressing in most of the Latin American countries, especially the rural areas thus requiring immediate intervention. Lacking sanitation and hygiene and availability of clean potable water were suggested to be the major determinants for such epidemics in these regions (Guthmann, 1995).

Foodborne illness is an important public health issue and the consumers around the globe are concerned with the safety of the foods. Venezuela, as a developing country has a week food safety system in place. Several studies have demonstrated perilous food supply system especially the seafood in this region. The fecal contamination of raw seafood (oysters) was investigated for the presence of enteric bacteria in Venezuela. The oysters were found to be heavily contaminated with *Proteus mirabilis* suggesting a potential human health risk associated with the consumption of raw seafood (Fernández-Delgado et al., 2007). Milk samples in Venezuela were also observed to carry heavy contamination such as *Staphylococcus*, *Streptococcus*, *Enterococcus Bacilli* (Faría Reyes et al., 2002).

Food safety in African developing countries

Literacy, access to basic necessities of life, food security, standards of living and policies and legislation are some of the primary drivers leading to food safety and economic growth. Food safety is an issue of paramount importance and has been identified as an instrumental determinant for huge disease burden, leading to destabilized and weak economy of developing countries of Africa. Most of the cases of

foodborne illness in Sub-Saharan African countries emanate from poor food supply system and microbiological contamination during production, processing, storage, and handling of several foods. Unsatisfactory conditions of hygiene and sanitation are highly prevalent and are linked with extreme poverty and resourcelessness in this region.

Several studies have reported unhygienic food supply and extensive contamination of commonly consumed foods, leading to high prevalence of foodborne illness in these areas e.g. bovine meat procured from slaughter house and tested for *E. coli* in Algeria indicated 7% of the total (230) samples contaminated with the pathogenic *E. coli* including *E. coli O157*, suggesting poor hygienic conditions of slaughterhouses (Chahed et al., 2006). Likewise *L. monocytogenes* have been implicated in raw milk, and raw milk products, posing a potential risk for consumers. Another study in Algeria confirmed that 2.61% of 153 and 7.50% 80 tested samples of farm milk and tankers' milk, respectively were found contaminated with *L. innocua* (Hamdi et al., 2007).

Like other developing countries of South Asia and Latin America, Salmonellosis prevails in South African regions where broiler farms and slaughterhouses have been regarded as major sources of contamination. Elgroud et al. (2009) reported high prevalence of *Salmonella* contamination of broiler farms (37%) and slaughterhouse (53%) in Constantine-Algeria. High prevalence of salmonella contamination in these regions highlights unsatisfactory hygiene practices throughout the supply chain. Causative microorganism for Typhoid-paratyphoid fever was 98% *S. typhi* in Algeria (Guechi & Hamza, 1992).

Foodborne illnesses of microbial origin are a major health problem associated with street foods (Mensah et al., 2002). Several studies have demonstrated high prevalence of various pathogenic microorganisms in a variety of street vended foods. Higher levels of enterotoxigenic *B. cereus* were observed in tested vegetable samples procured from streets of Gaborone, Botswana, suggesting risks associated with the consumption of street vended foods in South African regions. A similar study in Kumasi, Ghana revealed high prevalence of *Staphylococci* (23.7%), *Bacillus* spp. (21.5), and *S. aureus* (3.7%) in most of the tested foods. Contamination of 60 food samples with enteric bacteria and food poisoning organisms virtually represented a potential risk for local residents and was also a proxy for the poor hygiene and sanitation in the entire food chain in this area (Murindamombe et al., 2005; Feglo & Saky, 2012).

E. coli contamination in meat samples was assessed in 400 samples, collected from 15 supermarkets and butcheries in Gaborone, Botswana. Microbiological analysis manifested high prevalence of *E. coli* O157 i.e. 5.22% in meat cube samples, 3.76% in minced meat samples, and 2.26% in fresh sausages. Likewise, personal hygiene and the level of contamination through food handlers were evaluated among a total of 200 food handlers in Gaborone, Botswana for *S. aureus* contamination by sampling at various anatomical sites i.e. hand, nasal cavity, and face. The upshots of the study confirmed 115 handlers (57.5%) to be positive for *S. aureus*. The authors suggested training of vendors and improvement in environmental hygiene in this area (Magwira et al., 2005; Loeto et al., 2007).

Shiga toxin-producing *E. coli* and enteropathogenic *E. coli* isolated from mastitis milk in Egypt represented a greater risk for human health as these potentially pathogenic microorganisms belonged to serogroups associated with diarrhea and hemolytic-uremic syndrome (Osman et al., 2012). Consumption of raw or undercooked meat of bovine origin has been the most common means of transmitting this organism (Hiko et al., 2008). A group of researchers investigated the occurrence of *Salmonella* in foods in Morocco. The *Salmonella* prevalence levels observed were 71% for slaughterhouses and 9% for seafood (Beneduce et al., 2008). Similarly, presence of *Staphylococcal* strains in Morocco indicated another potential risk for foodborne illness in South African territories (Bendahou et al., 2008). Moreover, presence of *Alicyclobacillus* spp., a thermoacidophilic, nonpathogenic, spore-forming bacteria, in juices is now an important concern for beverage industry in South Africa because these bacteria have been found to contaminate high-acid concentrated fruit products (Steyn et al., 2011; Abdelgadir et al., 2008). Selected meat and meat products sold in the Amathole District Municipality of the Eastern Cape Province of South Africa were evaluated for *E. coli* O157:H7 and microbiological quality of these types of foods was found highly questionable (Abong'o & Momba, 2009).

Microbiological quality of Sudanese cultural foods was determined to gauge food safety and hygiene in this area. Traditional Sudanese fermented camel's milk product *Gariss* collected from nine different regions of Sudan and *Gergoush*, a naturally fermented Sudanese bread snack, were microbiologically evaluated. The results showed the presence of *S. infantarius*, a potential human pathogen, in these samples (Thorsen et al., 2011; Abdelgadir et al., 2008).

Zimbabwe is located in southern region of Africa and has a diverse food culture. Food safety status of Zimbabwean foods is highly hazardous and the indicators for such conditions resemble with adjoining states. Presence of high counts of *E. coli*, *S. aureus* and total viable bacteria in raw and processed milk indicated food safety to be an issue of public health significance (Mhone et al., 2011). Similarly, prepared food and drink tested for *E. coli* exhibited high contamination, suggesting a need for education to prevent cross contamination of foods (Simango & Mwakurudza, 2008).

Economic impact of foodborne illness

Considerable prevalence of foodborne illness has been well recognized in the developing nations; however, there is no statistical data available to assess the economic implications of this issue. This situation not only amplifies the existing economic losses due to foodborne illness but also hinders the overall national economic growth. Developed nations have a precise data to estimate such losses thus these data would indicate the extent of economic costs associated with foodborne illness. The Economic Research Service–USDA took the initiative to publish economic costs of foodborne illness in terms of medical costs, productivity losses and premature deaths resulting from various infections such Campylobacteriosis, *non-typhi Salmonella*, *E. coli* O157, *E. coli* non-O157 STEC and *L. monocytogene* in 2000 (Henson, 2003).

Estimated economic cost of foodborne illness by specific pathogens in the US only amounts to US $6.5 billion to $34.9 billion while £300–700 million were spent as medical cost in addition to value of lives in United Kingdom in 1996. A recent review on economic losses of foodborne illness in the United States presents the most comprehensive report to precisely depict the volume of economic loss incurred in US (Scharff, 2012). The statistics provided in this review could be a clear manifestation of the relative economic losses in countries of underdeveloped world due to foodborne infection. Little efforts were directed to compute economic losses linked with foodborne illness in India and Peru in 1988 and 1997 after an outbreak of *S. aureus* and cholerae outbreak, respectively. The economic loss seemed to occur in the form of loss of wages and medical cost in India while in Peru the same was indicated in the shape of a massive cholerae epidemic (Buzby & Roberts, 1997; Sudhakar et al., 1988).

The author remained unsuccessful to grasp any detailed data indicating the economic cost of foodborne diseases in South Asian and Latin American developing countries. This situation is a clear delineation of the complete absence of any mechanism to document food safety and related issues and to devise policies to fight against the challenging task of reducing foodborne illness in the region. However, WHO took the initiative to collect data on foodborne illness (Salmonellosis) in some developing countries by devising a systematic and risk assessment-based approach involving number of total estimated incidences caused by *non-typhi* and *paratyphi Salmonella* as a marker of the total diarrheal incidences (WHO, 2002).

Sub-Saharan Africa and India underwent the huge economic losses due to diarrheal disease i.e. 32% and 30%, respectively, suggesting foodborne illness and food safety issues to be the most potential barriers to national economic growth in these regions. Studies on the assessment of the economic loss of foodborne illness in numerical terms in the developing countries have been scarce (Henson, 2003). Precise data on economic loss of foodborne illness emanating from the developed world especially the United States constitute a very strong basis to assume that such losses could be quite massive in South Asian and African and Latin American developing countries. Infant diarrhea is one of the predominant indicators to multiply disease burden. Probably no significant fluxes elucidating any visible change in the last few decades in diarrhea incidence has been witnessed in these developing countries (Käferstein, 2003).

The cost of foodborne illness is calculated in terms of the economic loss born by the individual as cost of health care, absence from work and low productivity which subsequently mounts up national economic loss. South Asian, African and Latin American developing countries lack surveillance, reporting and documentation system for the incidence of microbiological outbreaks and individual cases of foodborne illness therefore figurative assessment can be made in terms of DALYs (Henson, 2003). Contrarily, this system is quite efficient and functional in developed world where every single case is generally recorded thereby providing evidence based statistical data to calculate such losses. Moreover, economic cost is reportedly higher in developing countries on the basis of percentage of per capita income as compared to the developed nations (Sudhakar et al., 1988).

Conclusions

Developing countries lack any integrated food safety framework which consequently poses a damaging impact throughout the food supply chain. Microbiological contamination of food and resulting foodborne illness are therefore, a routine incidence in underdeveloped nations especially the countries of South Asia, Latin America and Africa, though majority of the foodborne illness cases go unreported and unrecognized. Botulism, campylobacteriosis, *E. coli* infection, *Staphylococcus aureus* infection, salmonellosis, listeriosis and C*holerae* are of particular concern with food safety standpoint in these poorer economies. Assuring food safety in different food chains like industries, hotels and restaurants may be achieved through strict monitoring and surveillance in the countries of third world. Moreover, street vending of foods is believed to be a potential cause of illness and thus needs to be precisely focused. Assessment of the burden of foodborne infections and identification of foodborne illness outbreaks obviously are not possible without monitoring and surveillance. This target to strengthening surveillance and disease control is hard to achieve in the absence of political commitment, intervention of international agencies, awareness and strict legislation in the developing world. Implementation of HACCP and food safety management systems (ISO 22000) is scant. The food industries and allied entrepreneurs are often inclined to get them certified in the developing countries as a strategy to promote business and often evade applying the systems with a professional spirit. Conclusively, the prevailing food safety situation is highly precarious in the developing countries and the recent challenges like antibiotic resistance, emergence of new and more stubborn bacterial strains and increasing demand for food to feed the rapidly growing population among the nations of developing world need to be sagaciously addressed for wellness and prosperity in these regions.

Declaration of interest

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