

Salmonellosis As a Global Foodborne Pathogen: A Review

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Abstract

Salmonella is a ubiquitous bacterium of worldwide public health concern, contributing to the economic burden of both industrialized and underdeveloped countries through the costs associated with surveillance, prevention, and treatment of disease. At this time, over 2500 Salmonella serotypes have been recognized and more than half of them belong to Salmonella enterica subsp. enterica, which accounts for the majority of Salmonella infections in humans. This review aims to highlight the background information on Salmonella as a food-borne pathogen and illustrate the breaking point of this food-borne pathogen along with its economic and public health burden. The pathogen naturally exists in the environment and animals and its byproducts. Food-borne transmission is recognized as the major cause of salmonella infections. Poultry, pigs, and cattle, and their products like meat, eggs, and milk are most commonly identified as food sources responsible for outbreaks of human salmonellosis. Risk factors like the habit of raw animal product consumption, unstandardized slaughtering process, and nonhygienic food-preparation procedures may put people at of Salmonella infection. Thus, to the effect collaboration between human and veterinary practitioners is very crucial to increase the awareness and education toward the disease, especially among susceptible risky groups.

Keywords: Contamination, Foodborne, Public Health, Salmonella.

Introduction

Foodborne diseases (FBDs) are among the most widespread global public health problems of recent times, and their implication for health and economy is increasingly recognized (Hendriksen *et al.*, 2011). The general ultimate goal of all food safety programs is to halt contaminated food products from reaching the consumer. Henceforth, surveillance for food-borne diseases is being conducted in different parts of the world to delineate the occurrence and burden of important public health concerns (Olasunmbo *et al.*, 2014, Dagnev *et al.*, 2020). *Salmonella* is one of the most frequently isolated foodborne pathogens and Salmonellosis is one of the major foodborne diseases in the world (Sharkawy *et al.*, 2017), and it is estimated that 93.8 million cases of gastroenteritis due to *Salmonella* species occur globally each year, with 230,000 deaths (Majowicz *et al.*, 2010, WHO. 2019). In recent years, the World Health Organization reported that the incidence and severity of cases of salmonellosis have increased significantly (WHO, 2020). The vertical and horizontal transmission ability of *Salmonella* along with its ability to acquire antimicrobial resistance (AMR) is the worst part of this pathogen rendering it difficult to eliminate. The emergence and spread of such resistant strains among food animals is life-threatening and a global public health concern, as they are often non-treatable with currently available antimicrobials (Liljebjelke *et al.*, 2005, Abdi *et al.*, 2017).

Salmonella is one of the most prevalent zoonotic pathogens in both developed and developing countries (Velusamy *et al.*, 2010). The causative agent is a facultative anaerobic Gram-negative rod that grows optimally at 35°C to 37°C, oxidase negative, urea negative, catalase positive, indole and Voges Proskauer (VP) negative, methyl red and Simmons citrate positive, H₂S gas producers, non-spore-forming, and straight rods belonging to the *Enterobacteriaceae* family (Quinn, 2000; Chlebicz *et al.*, 2018). The genus comprises two species: *Salmonella enterica* (*S. enterica*) and *Salmonella bongori* (*S. bongori*) (Grimont and Weill, 2007) under which greater than 2,500 serotypes identified (Musa *et al.*, 2017). *S. enterica* is further classed into six subspecies (Dhama *et al.*, 2013) and is a major pathogen in humans as well as in animals (Musa *et al.*, 2017; Tegegne, 2019). More than 150 serotypes can cause food-borne salmonellosis (Dhama *et al.*, 2013). However, *S. typhimurium* and *S. enteritidis* are more common (Dhama *et al.*, 2013; Tadesse and Tessema, 2004; Tegegne, 2019).

The pathogen causes foodborne poisoning in humans, mainly infection occurs through the consumption of contaminated animal-derived food products that include meat, eggs, raw and milk, and contact with animals (Ayers and Farah, 2006, Ali *et al.*, 2020). Contamination of these foods can occur during production, processing, and distribution (Kebede *et al.*, 2016). Poultry and other food animals are considered the common reservoirs of *Salmonella enterica* and consumption of undercooked poultry products is the major source of human infection with non-typhoidal *Salmonella*, which causes diarrhoeal and invasive disease (FAO, 2019). As it has been revealed by different investigations, *Salmonella* serovars which are most prevalent in humans are also common in poultry suggesting a possible epidemiologic connotation that poultry is a reservoir of human *Salmonella* infection. Foley *et al.*, (2011) for instance, indicated that *S. Enteritidis* and *S. Heidelberg* were the most frequently isolated serovars in the United States, which were also among the top serovars causing human infection. Similarly, *S. infantis*, *S. Stanley*, and *S. Kentucky* were serovars originating from poultry meat and are also reported to be associated with human salmonellosis in European countries (Antunes *et al.*, 2016). Studies from developing countries like Ethiopia also showed genetic relatedness of *S. Kentucky* and *S. Anatum* isolated from poultry and diarrheic human patients using pulsed-field gel electrophoresis and isolates displayed similar antimicrobial resistance phenotype suggesting the possibility of poultry to be a source of human infection (Egualé *et al.*, 2018, Dagnev *et al.*, 2020).

Generally, *Salmonella* infection remains a major public health concern worldwide, contributing to the economic burden of both industrialized and underdeveloped countries, through the costs associated with surveillance, prevention, and treatment of the disease (Crump *et al.* 2004; Haileselassie *et al.*, 2013). Apart from the morbidity and mortality costs in humans and animals, restrictions to trade and discard contaminated food are important socioeconomic problems of the bacteria (Abdi *et al.*, 2017). However, there is a lack of well-organized and documented information on food-borne diseases as whole and *salmonella* specifically in Ethiopia as well as in most developing countries.

Therefore, the objective of this review paper is to review *Salmonella* as a food-borne pathogens and its economic and public health importance.

Literature Review

History and Nomenclature

In brevity, *Salmonella* was first discovered and isolated from the intestines of porcine infected with classical swine fever, by Theobald Smith in 1855 and his colleague Salmon. The bacterial strain was named after Dr Daniel Elmer Salmon, an American veterinary pathologist who worked with Smith (Pal, 2013). The classification and nomenclature of *Salmonella* have been controversial for many years. Currently, the Centers for Disease Control and Prevention (CDC) uses the nomenclatural system of *Salmonella* recommended by the World Health Organization (WHO) Collaborating Centre (Popoff *et al.* 2003, CDC, 2012). According to this system, the genus *Salmonella* is classified into two species, *Salmonella enterica* (type species) and *Salmonella bongori*, based on differences in their 16S rRNA sequence analysis. The type species, *S. enterica*, can be further classified into six subspecies based on their genomic relatedness and biochemical properties (Reeves *et al.* 1989; Eguale *et al.*, 2018). These are *S. enterica* subsp. *Enterica* (I), *S. enterica* subsp. *Salamae* (II), *S. enterica* subsp. *Arizonae* (IIIa), *S. enterica* subsp. *Diarizonae* (IIIb), *S. enterica* subsp. *Houtenae* (IV) and *S. enterica* subsp. *Indica* (VI) (Grimont and Weill, 2007). Out of these subspecies, *S. enterica* subsp. *enterica* (I) is found predominantly in mammals and contributes approximately 99% of *Salmonella* infections in humans and warm-blooded animals (Shu-KeeEng *et al.*, 2015). In contrast, the other five *Salmonella* subspecies and *S. bongori* are found mainly in the environment and cold-blooded animals, and hence are rare in humans (Brenner *et al.* 2000).

In addition to classification into subspecies, the species are further sub-classified into serotypes using the Kauffman-White scheme, which is defined and maintained by the WHO Collaborating Center for Reference and Research on *salmonella* at the Pasteur Institute, Paris, France. The classification is based on the extensive diversity of lipopolysaccharide antigen (*O* antigen), flagellar protein antigen (*H* antigen), and sometimes the capsular (VI) antigens. Currently, there are more than 2500 serotypes of *Salmonella*, and new serotypes are listed on annual updates of the Kauffman-White scheme (Grimont and Weill, 2007), out of which more than 150 serotypes can cause food-borne salmonellosis (Dhama *et al.*, 2013).

Pathogenesis

The severity of *Salmonella* infections in humans varies depending on the serotype involved and the health status of the animal and human host. Almost all strains of *Salmonella* are pathogenic as they can invade, replicate, and survive in human host cells, resulting in potentially fatal disease (Shu-KeeEng *et al.*, 2015). Factors such as strain virulence, infectious dose, route of infection, and host susceptibility mediate the pathogenicity of the organism. Virulence factors such as virulence plasmids, toxins, fimbriae, and flagella help in establishing an infection (Kemal *et al.*, 2015). The product of several chromosomal genes mediates the complex invasion process, whereas growth within the host cell depends on the presence of virulence plasmids (Addis and Sisay, 2015). Microfold (M) cells are the target cells of *Salmonella* pathogenicity. Some of the mechanisms of pathogenesis are bacterial-mediated endocytosis, neutrophil recruitment and migration, epithelial cell cytokine secretion, fluid and electrolyte secretion, and systemic infection (Kemal *et al.*, 2015).

Normal flora protects against colonization and administration of oral antibiotics facilitates the establishment of infection (Addis and Sisay, 2015). *Salmonella* avoids host defense in the stomach, reaches the intestines, and interacts with the nonphagocytic cells such as the epithelial cells of the intestinal mucosa. They adhere to the intestinal epithelial cells by fimbriae (adhesive structures) that promote binding and invade epithelial cells to provoke gastroenteritis (Kemal *et al.*, 2015). Enteric infection is characterized by local damage without septicemia-*salmonella* infection with microfold cells in Peyer's patches, which is facilitated by fimbrial adhesions. This is followed by the ruffling of the target cell membrane, which results in the internalization of the bacteria in membrane-bound vacuoles. The ruffles facilitate the uptake of the bacteria in membrane-bound vacuoles or vesicles, which often coalesce (Addis and Sisay, 2015, Abebe *et al.*, 2020).

Epidemiological Distribution

Salmonella is one of the major public health concerns all over the world. It is the most common food-borne disease in both developing and developed countries, although incidence rates vary according to the country (Tadesse and Gebremedhin, 2015). Salmonellosis is one of the most important bacterial zoonoses that affects both humans and

animals throughout the world (Ralph, 2000; Pal, 2013 Tadesse, 2014). Approximately, 93.8 million human cases of salmonellosis are reported annually around the world (Majowic *et al.*, 2010).

Distributions of Typhoid Salmonella and Non-typhoid Salmonella infections

Salmonella is one of the known food-borne pathogens with major public health and economic concerns all over the world. It is the most common food-borne disease in both developing and developed countries, although incidence rates vary according to the country (Pal, 2007; Addis *et al.*, 2011; Tadesse and Gebremedhin, 2015). The disease has been recognized in all countries but appears to be most prevalent in areas of intensive animal husbandry, especially poultry and swine production. For epidemiological purposes, *Salmonella* can be placed into three groups: Those that infect humans only: Include *S. Typhi*, *S. ParatyphiA*, and *S. Paratyphi C*. This group includes the agents of typhoid and paratyphoid fevers, which are the most severe of all diseases caused by *salmonellae*. Typhoid fever has the longest incubation time, produces the highest body temperature, and has the highest mortality rate. *S. Typhi* may be isolated from blood and sometimes the stool and urine of victims before enteric fever. The paratyphoid syndrome is milder than that of typhoid. The host-adapted serovars include *S. Gallinarum* (poultry), *S. Dublin* (cattle), *S. Abortus-equi* (horses), *S. Abortus-ovis* (sheep), and *S. Choleraesuis* (swine); and the host un-adapted serovars have no host preference. These are pathogenic for humans and other animals, and they include most food-borne serovars (Jay, 2000; Radiostits *et al.*, 2007)

Source of Infection and Route of Transmission

The pathogen naturally occurs in the environment and animals and its byproducts. Food-borne transmission is recognized as the major cause of *salmonella* infections (Ejo *et al.*, 2016). Even though human infection occurs via ingestion of contaminated water and food with animal faeces, and food-processing equipment, animal-origin food and their products are the commonest vehicles of *Salmonella* to humans (Dhama *et al.*, 2013; Kemal *et al.*, 2015). Importantly, contaminated water or food is the major transmission route of enteric fever. In this case, it is possible to minimize the incidence of *Salmonella* infection with proper food and water sanitation, pasteurization of milk and other dairy products, and elimination of the use of human faeces in food production (Shu-KeeEng *et al.*, 2015). Contaminated animal products usually result from infected animals used in food production or from contamination of the carcasses or edible organs. Fecal or intestinal contamination of carcasses is the principal source of human food-borne infections. The exception is when *Salmonella* is directly transmitted into the food product. Cross-contamination of carcasses with *Salmonella* can also occur during slaughtering operations (Tegegne, 2019). Eggshells and egg contents can be contaminated by this bacterium during egg formation in the hen's reproductive system or from the environment including fecal contact (Taddese *et al.*, 2019). In their review, Abebe *et al.*, (2020), indicated that the recently emerged *S. typhimurium*DT104, which is known as a multidrug-resistant definitive type, is mainly transmitted through ingestion of contaminated beef

Risk Factors for Animal Infections

Salmonella is found naturally in the environment and both domestic and wild animals (Heredia and. Garcia, 2018). The prominent epidemiological factor is the common carrier status in animals. The primary habitat of *Salmonella* species is the intestinal tract of animals such as farm animals, humans, birds, reptiles, and insects. Animals are the reservoir of food-borne diseases of *Salmonella* (Addis M. and. Sisay, 2015).

Risk Factors for Human Infection

Nontyphoidal Salmonella species (including all *Salmonella* strains other than *S. Typhi* and *S. Paratyphi*, which are known as *typhoidal salmonella* (Connor & Schwartz 2005)) are zoonotic agents, and food products of animal origin are the main sources for their transmission (Tegegne, 2019). Poultry, pigs, and cattle, and their products like meat, eggs, and milk are most commonly identified as food sources responsible for outbreaks of human salmonellosis (Kassaye *et al.*, 2015; Heredia and. Garcia, 2018; Taddese *et al.*, 2019) although the microorganism has also been found in another foodstuff. Chicken products including eggs are widely acknowledged to be a significant reservoir of *Salmonella* and have been consistently implicated in sporadic cases and the outbreak of human salmonellosis (Kemal *et al.*, 2015; Balakrishnan *et al.*, 2018).

Consumption of raw or unsafe food, cross-contamination, improper food storage, poor personal hygiene practices,

inadequate cooling and reheating of food items, and a prolonged time lapse between preparing and consuming food items were mentioned as contributing factors to an outbreak of salmonellosis in humans (Pal *et al.*, 2015; Ijo *et al.*, 2016). The bacteria enter the food chain at any point in livestock feed, and in food manufacturing, processing, retailing, catering, and preparation, survive typical catering refrigeration temperatures, and increase in number under conditions of thermal abuse (Tadesse and Gebremedhin, 2015). Antibiotic-resistant *salmonella* infections of both humans and animals are universal concerns, particularly in developing countries, where the risk of infection is high because of unhygienic living conditions, close contact and sharing of houses between animals and humans, and the traditions of consumption of raw or undercooked animal-origin food items (Ejo *et al.*, 2016).

Foodborne Burden of Salmonellosis

The burden of foodborne diseases is borne by individuals of all ages, but particularly by children under 5 years of age, and by persons living in low-income subregions of the world. It has been indicated that Foodborne diseases are an important cause of morbidity and mortality, and a significant impediment to socioeconomic development worldwide (Crump and Heyderman, 2014). From 2007-2015, an Initiative group known as WHO- FERG estimated the Global Burden of Foodborne Diseases in case of incidence, mortality, and disease burden in terms of Disability Adjusted Life Years (DALYs) and provided that 31 global hazards caused 600 million foodborne illnesses and 420,000 deaths in 2010. In that case, the initiatives recited that the most frequent causes of foodborne illness were diarrhoeal disease agents. Foodborne diarrhoeal disease agents caused 230,000 deaths, which was particularly attributed to *non-typhoidal Salmonella enterica* (WHO, 2017).

Both the nontyphoidal *salmonella* (NTS) infections and typhoidal *Salmonella* (TS) infection are known to pose great food borne burden in different parts of the world even though NTS is the most. NTS infections, which cause self-limited illness, are the most common *Salmonella* infections and occur worldwide whereas the enteric fever, caused by typhoid *Salmonella*, is associated with a high morbidity and mortality rate and occurs predominantly in underdeveloped countries (Hardy 2004). Nontyphoidal *Salmonella* are most important zoonotic bacterial food-borne pathogens of humans. *Salmonellae* are widely distributed in nature (Kemal *et al.*, 2015), and they are the major pathogenic bacteria in humans as well as in animals. They are most frequently isolated bacterial agents of food-borne disease outbreaks (Balakrishnan *et al.*, 2018), and they account around 93.8 million food-borne illnesses and 155,000 deaths per year worldwide (Heredia and Garci, 2018). More or less the emergence and spread of antimicrobial-resistant *Salmonella* strains have become a serious health hazard worldwide (Prestinaci *et al.*, 2015). It is believed that the widespread use of antimicrobials in food-producing animals during rearing has been contributed to the occurrence of *Salmonella* with decreased susceptibility to antimicrobials (Angulo *et al.*, 2000).

The Clinical Features

Different *Salmonellae* serovars have been incriminated as a major and serious food-borne zoonosis of public health significance. Based on the clinical patterns in human salmonellosis, *Salmonella* strains can be grouped into typhoid *Salmonella* and non-typhoid *Salmonella* (NTS). *Salmonella Typhi* causes typhoid fever whereas Paratyphi A, B and C cause paratyphoid fever with symptoms, that are milder, and a mortality rate that is lower for the latter. Both serotypes are solely human pathogens. Infection typically occurs due to ingestion of food or water contaminated with human waste (Pui *et al.*, 2011). Typhoid fever is usually manifested by gastrointestinal symptoms, but some cases may show various clinical syndromes like disseminated intravascular coagulation and acute respiratory distress syndrome. The clinical disease usually appears after 12-72 hours of infection and is characterized by diarrhea with fever, nausea, vomiting, abdominal pain, headache, bradycardia, and cough (Pandit *et al.*, 2008; Abd El-Ghany, 2020).

Non-typhoid *Salmonella* (NTS) infections are characterized by gastroenteritis or 'stomach flu', an inflammatory condition of the gastrointestinal tract which is accompanied by symptoms such as non-bloody diarrhoea, vomiting, nausea, headache, abdominal cramps, and myalgias. Symptoms such as hepatomegaly and splenomegaly are less commonly observed in patients infected with NTS (Hohmann 2001). Compared to typhoid infections, NTS infections have a shorter incubation period (6–12 h) and the symptoms are usually self-limiting and last only for 10 days or less (Crump *et al.* 2008). Gastrointestinal complications of NTS infections include cholecystitis, pancreatitis, and appendicitis, while the perforation of the terminal ileum has no association with NTS infections (Hohmann 2001). Infants, young children, elderly people, and immunocompromised patients are highly susceptible to NTS infections and develop more severe symptoms than normal individuals (Scallan *et al.* 2011). Infection always occurs

via ingestion of water or food contaminated with animal waste rather than human waste. The emergence of multidrug-resistant *S. Typhimurium* DT104 has been associated with outbreaks related to beef contamination and resulted in hospitalization rates twice that of another foodborne salmonellosis (Gray and Fedorka-Cray, 2002; Abebe *et al.*, 2020).

Antibiotic Resistance

The emergence of antimicrobial resistance in *Salmonella* strains is a serious health problem worldwide (Chiu *et al.* 2002). In the early 1960s, the first incidence of *Salmonella* resistance to a single antibiotic, namely chloramphenicol, was reported (Montville & Matthews 2008). Since then, the frequency of isolation of *Salmonella* strains with resistance towards one or more antimicrobial agents has increased in many countries, including the USA, the UK, and Saudi Arabia (Yoke-Kqueen *et al.* 2008). Antimicrobial agents such as ampicillin, chloramphenicol, and trimethoprim–sulfamethoxazole is used as the traditional first-line treatments for *Salmonella* infections. *Salmonella* spp. resistant towards these agents are referred to as multi-drug resistant (MDR). The widespread prevalence of multidrug-resistant (MDR) isolates has been recorded and, this has influenced the impact of typhoid fever in developing countries (EFSA, 2013). In *S. Enterica* antimicrobial resistance (AMR) genes were detected in 68% of isolates from meat and dairy products (Ahmed *et al.*, 2013). Moreover, more than 43 isolates of *Salmonella* from chicken beddings and humans exhibited resistance to kanamycin and sulfamethoxazole-trimethoprim, nalidixic acid, ampicillin, cefoxitin, streptomycin, tetracycline, chloramphenicol, ciprofloxacin, and gentamicin (Abdi *et al.*, 2017). Lately, in 2019, Elkenany *et al.* (2019) demonstrated AMR genes in 76.7% of *S. Enterica* strains isolated from broiler chicken farms and chicken carcasses in retail shops in El-Sharkia province, in Egypt. In a study carried out in Lower Egypt, AMR genes of *Salmonella* Typhi isolated from 29% of patients showed resistance to chloramphenicol, ampicillin, and trimethoprim-sulfamethoxazole (Srikantiah *et al.*, 2016)

To date, the emergence of *Salmonella* serotypes resistant to quinolones and cephalosporin poses a new challenge in treating infected patients, and the lack of effective antibiotic therapy may lead to an increase in the morbidity and mortality rates (Shu-KeeEng *et al.*, 2015). The emergence of MDR *Salmonella* has also resulted in the increased severity of bacterial infections in humans and animals. Epidemiological studies show that MDR *Salmonella* strains cause more severe or prolonged syndromes than susceptible strains, implying that the MDR strains are more virulent than the susceptible ones (Travers & Barza 2002). Patients infected with MDR *Salmonella* strains are more ill and septic at the onset of the disease, and the illness is typically accompanied by high fever, enlargement of the spleen and liver, and abdominal swelling (Abebe *et al.*, 2017).

Prevention Methods

Reducing Animal Product Contamination

Food products may become contaminated at different stages along the food chain (Hemalata and Virupakshaiyah. 2016), and could be during production, processing, distribution, preparation, and/or final consumption. The risk of food getting contaminated depends largely on the health status of the food handlers, their personal hygiene, knowledge, and practice of food hygiene (Aklilu *et al.*, 2015). As defined by WHO, food-borne diseases are diseases of infectious or toxic nature, which are caused by the consumption of food or water. Intoxication (a toxin produced by the pathogens that cause food poisoning), infection (ingestion of food containing pathogens), and toxic infections (producing toxins while growing in the human intestines) are the three types of food-borne diseases (Dhama *et al.*, 2013). Food-borne microbes are major problems affecting food safety and cause human infections after consumption of animal products contaminated with microorganisms or their toxins, hence, minimization of food contamination is considered a mainstay in preventing the risk of getting *salmonella* infection, which can be achieved at production, transportation and service stages (Heredia and Garcia, 2018; Abebe *et al.*, 2020).

Instating biosecurity and biocontainment practices in addition to enhanced food processing methods and preparation and storage practices are required to control and prevent food spoilage due to *Salmonella* (Addis and Sisay, 2015). Safe food preparation practices including cooking, reheating of food, pasteurization (boiling) of milk, adequate refrigeration, and exclusion of pets and other animals from food-handling areas should be carried out. Additional measures to control secondary contamination could be the prevention of contamination by cleaning and disinfection, hygiene of personnel, and proper processing (Kemal *et al.*, 2015). Vulnerable groups are advised to avoid consuming undercooked meat and poultry, raw milk, eggs, and foods that contain raw eggs (Addis and Sisay, 2015).

Environmental Management

Contaminated water or food is the major transmission route of enteric fever. Actually, environment contaminated with *Salmonella* serves as the infection source because *Salmonella* can survive in the environment for a long time. After that, *Salmonella* is transmitted to vectors such as rats, flies, and birds where *Salmonella* can shed in their faeces for weeks and even months. Following the direct transmission, moving animals such as pigs, cows, and chickens act as an important risk factor for infection. These animal reservoirs are infected orally because *Salmonella* normally originates from a contaminated environment and contaminated feed (Newell *et al.*, 2010). Proper sanitation, correct sewage disposal, and provision of a clean water system can minimize the transmission of typhoid fever. The intervention strategies including *Salmonellae* monitoring programs along the farm-to-table continuum should be started in the environment around the contamination aforementioned. Environmental cleaning from both human and animal feces can be mentioned as a means in reducing the environmental burden the pathogens, hence limiting transmission to human beings (Patrick *et al.*, 2004).

Status of Salmonellosis in Ethiopia

In this century, it is obvious that food-borne diseases are public health problems in both developed and developing countries. Thousands of millions of people fall ill and may die because of eating unsafe food (WHO, 2012). Biological contaminants largely bacteria, constitute the major cause of food-borne diseases. *Salmonella* infection most commonly occurs in countries with poor standards of hygiene in food preparation and handling and where sanitary disposal of sewage is lacking (Senthikumar and Prabakaran, 2005; Käferstein, 2020). Studies indicated the widespread occurrence and distribution of *Salmonella* in Ethiopia. In Ethiopia, minced beef is usually used for the preparation of a popular traditional Ethiopian dish known as locally “*Kitfo*” and most of the time it is consumed raw or medium cooked. The habit of raw meat consumption and the presence of *Salmonella* in minced beef indicates, in addition to the poor hygienic standards in food handling in the country, the presence of great public health hazards of *Salmonella* (Muleta and Ashenaf, 2001). Investigations conducted in different parts of Ethiopia have confirmed the presence of *Salmonella* in human beings, different food animals, and food of animal origin. Despite there are reports on the prevalence and distribution of *Salmonella* species in the country, the problem of these pathogens in food of animal origin is still not well known. Moreover, the risk factors associated with the contamination of animal products are not described, and the incidence of food-borne salmonellosis is still unknown in the country (Tadesse and Gebremedhin, 2015; Ejo *et al.*, 2016). Occurrence of carrier food animals, illegal slaughtering of animals in open fields, unhygienic slaughter practices in the abattoirs, and widespread tradition of consumption of raw meat are potential risk factors for *salmonella* infection in the country (Assefa and Bihon, 2018). A few published findings on the prevalence of nontyphoidal *Salmonella* in different parts of Ethiopia are shown in Table (1).

Table 1: Distributions of *Salmonella* in different parts of Ethiopia

Locations	Species	Sample type	Prev %	Reference (s)
Central Ethiopia	shoats	Faeces, mesenteric lymph nodes, liver, spleen, and abdominal and diaphragmatic muscle	1.8	Molla <i>et al.</i> , 2006
Addis Ababa	cattle	Faecal and milk	10.76	Addis <i>et al.</i> , 2011
Addis Ababa	shoats	Liver, kidney, spleen, muscle, carcass, mesenteric lymph node and feces	1.04	Kassaye <i>et al.</i> , 2015
Gondar	cattle	Raw meat and swab	17.30	Garedew <i>et al.</i> , 2015
Holeta	cattle	Rectal feces, udder milk, pooled milkers, hand swab, tank milk, tank swabs, and bucket swabs	5.60	Abunna <i>et al.</i> , 2017
Asella	cattle	Carcass swab, Hanging material swab, Knife swab, Hand swab, lymph node, Faeces, milk	6.50	Beyene <i>et al.</i> , 2016
Gondar	**	Raw meat, minced meat, burgers, raw eggs, and raw milk.	5.50	Ejo <i>et al.</i> , 2016
Addis Ababa	cattle	Fecal and carcass swab	3.70	Ketema <i>et al.</i> , 2018
Dessie	cattle	Meat, eviscerating knives	4.95	Amera <i>et al.</i> , 2017
Bahir Dar	cattle	Meat	70	Azage, 2017
Modjo	shoats	Cecum, liver, mesenteric lymph nodes,	17.21	Kuma <i>et al.</i> , 2017

and Bishoftu		abdominal muscle		
Ambo	cattle	Mesenteric lymph nodes and feces	8	Mustefa, 2018
Wolaita Sodo	cattle	Abdomen, thorax, crutch, and breast	12.50	Wabeto <i>et al.</i> , 2017
Addis Ababa	cattle	Feces, carcass swabs, milk	7.50	Banti, 2018
Addis Ababa and Mojo	poultry	cloacal swabs, fecal droppings, feed samples, and floor swabs	2.9	Dagnew <i>et al.</i> , 2020
Modjo	poultry	cloacal swabs, fresh feces, pooled litter, drinking water	15.12	Abunna <i>et al.</i> , 2017
Central Ethiopia	poultry	chicken table eggs	11.5	Aseffa <i>et al.</i> , 2011
Addis Ababa	cattle	Butter, yogurt, milk	1.6	Liyuwork <i>et al.</i> , 2013
	poultry	Feces, hand swab, bedding	16.7	Abdi <i>et al.</i> , 2017

**=animal origin food items; prev % =prevalence in percentage

Conclusion and Recommendations

Food-borne pathogens are the leading causes of human illness worldwide with a great burden in developing countries resulting in huge economic loss in addition to public health issues. From this review, it was concluded that *Salmonella* is one of the most frequently isolated foodborne pathogens and Salmonellosis is one of the major foodborne diseases in the world. It was estimated that 93.8 million cases of gastroenteritis due to *Salmonella* species occur globally each year, with 230,000 deaths. This bacterium can enter into the food chain from the production of food animals up to the final consumption of animal products. Moreover, currently, *Salmonella* has a great concern for public health due to the emergence of multidrug-resistant strains. Proper handling and cooking of food are measures proposed to eradicate the bacterial contamination of food. Risk factors like the habit of raw animal product consumption, unstandardized slaughtering process, and nonhygienic food-preparation procedures and handling may prone people to food-borne pathogens in general and *Salmonella* in particular in the country. Based on the above conclusion, the following recommendations are pinpointed:

1. Good manufacturing practices, standardized slaughtering and pasteurization procedures, and hygienic animal product-preparation techniques should be properly implemented
2. Awareness to the public should be created so that people can focus on the prevention of the burden of salmonella pathogens on their health and, animals.
3. Collaboration between human and veterinary practitioners is very crucial to increase awareness and education toward the disease's importance especially among susceptible risky groups.

List of Abbreviations

AMR: Antimicrobial Resistance Gene; CDC: Center for Disease Control; FAO: Food and Agricultural Organizations; FBD: Food Borne Disease; MDR: Multidrug Resistance; WHO: World Health Organization

Contribution by Authors

Equal contribution. All authors declared that 'written informed' consent was obtained from the approved parties for the publication of this article and accompanying images.

Conflict of Interests

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