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Review on Salmonella and Its Public Health Importance

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ABSTRACT

Salmonellosis is caused by *salmonella* organism, which is a gram negative, flagellated, facultative anaerobic, rod shaped, belongs to family of Enterobacteriaceae. Salmonellosis is an infectious disease of humans and animals caused by organisms of the two species of *Salmonella* (*Salmonella enterica*, and *Salmonella bongori*). Although primarily intestinal bacteria, *salmonella* are widespread in the environment and commonly found in farm effluents, human sewage and in any material subject to fecal contamination. *Salmonella* has significant public health implications causing food borne and zoonotic diseases in humans. Foodborne salmonellosis often follows consumption of contaminated animal products, which usually results from infected animals used in food production or from contamination of the carcasses or edible organs poultry and poultry-related products. Affected individual's experience sudden nausea, vomiting and watery fouwl smelling diarrhea which is in most case last only a few days. The economic loss associated in human salmonellosis is due to investigation, treatment and prevention of illness. Pasteurization of milk and treating municipals water supply for reducing risk of *Salmonella* infection, improvement in farm animal hygiene in slaughter process in food harvesting and in packaging operation have helped to prevent salmonellosis. In general, food animals such as swine, poultry and cattle are the prime sources of *Salmonella* infections. Therefore, the objective of this paper is to review the public health importance of *salmonella* and associated risk factors.

Key word:- *Contamination, Fecal, Food born infection, Salmonella, Zoonosis*.
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1. INTRODUCTION

Ethiopia has the largest livestock population in Africa, with 65 million cattle, 40 million sheep, 51 million goats, 8 million camels and 49 million chickens [1]. Livestock sector contributes about 45% to the agricultural gross domestic product (GDP), 18.7% to the national GDP, and 16–19% to the total foreign exchange earnings of the country. It is the source of industrial raw materials (milk, meat, and hides and skin) and high-value protein to potential consumers in Ethiopia [2].

Consumption of animal products like meat, milk, and egg is increased due to rapid human population growth, urbanization, per capita income raise, globalization, and the changes on consumer habits (preference of high-protein diet) is situation results in a high demand of food of animal origin and leads to intensive animal production and processing of products, especially mass production and movement of products globally. During this time, there may be defective processing practices at any point of the farm to fork chain which increase the chances of contamination and spread of food-borne pathogens [3]. Food products may become contaminated at different stages along the food chain, could be during production, processing, distribution, preparation, and/or final consumption [4].

Food-borne diseases remain a major public health problem across the globe. The problem is severe in developing countries due to difficulties in securing optimal hygienic food handling practices. Risk of food getting contaminated depends largely on the health status of the food handlers, their personal hygiene, knowledge, and practice of food hygiene [5]. According to the WHO, 30% of the population suffers from food-borne diseases each year in developed countries, and up to 2 million deaths are estimated per year in developing countries [6]. In developing countries, up to 70% of cases of diarrheal disease are associated with the consumption of contaminated food [7].

Food can be contaminated by physical, chemical, and microbiological agents. The microbial agents responsible for food-borne diseases are bacteria, viruses, parasites, and fungi [8]. Diseases of animal origin can be transmitted between humans and animals through direct contact, indirect contact, environmental contact, and/or through food consumption [9]. Around 60% of human diseases originated from animals, and approximately 75% of new emerging human infectious diseases are transmitted from vertebrate animals to humans [10].Food-borne microbes are major problems affecting food safety and causes human infections after consumption of the animal products contaminated with microorganisms or their toxins. Most of the pathogens have a zoonotic origin, and food products of animal origin are considered as major vehicles of food-borne infections [11]. Food-producing animals (cattle, chickens, pigs and turkey) and animal products (meat, milk, egg and fish) have high risk due to pathogen contents, natural toxins, adulterants and other possible contaminants [12]. Compared to other parts of the hand, the area beneath the fingernails harbors the most micro- organisms and is most difficult to clean[13]. Salmonellosis is linked to the consumption of *salmonella*-contaminated food products mostly from poultry, pork and egg products. Poor hand washing and contact with infected pets are some of the contamination routes. When infective doses are ingested, the pathogen causes sickness by colonizing the intestinal tract [14].

Infections with *Salmonella* in food-producing animals present a serious public health concern, because food products of animal origin are considered to be a significant source of human infection. Milk and dairy products have also been associated with outbreaks of salmonellosis in people. In addition, contamination of fruit and vegetables by infected water may also be a source of infection [15]. *Salmonella,* although being intestinal bacteria, are widespread in the environment and are commonly found in farm effluents and in any material subjected to fecal contamination[16].

Contamination of meat (cattle, pigs and poultry) may originate from animal salmonellosis, but most often it results from the contamination of meat with intestinal contents during evisceration of animals, washing, and transportation of carcasses [17]. Likewise, vegetables and fruits may carry *Salmonella* if contaminated with fertilizers of fecal origin, or when washed with polluted water [18]. Prevailing poor food handling and sanitation practices, inadequate food safety laws, weak regulatory systems, lack of financial resources to invest in safer equipment, and lack of education for food handlers are the reasons for common occurrence of food-borne diseases in developing countries including Ethiopia [19].

The habit of raw beef consumption. overcrowding, poverty, inadequate sanitary conditions, and poor general hygiene are also the factors of food-borne diseases in Ethiopia [20]. The slaughtering process of food animals at abattoirs is considered one of the important sources of organ and carcass contamination with *Salmonella* [21]. In Ethiopia, minced beef is usually used for the preparation of a popular traditional Ethiopian dish known locally as "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 indicate, in addition to the poor hygienic standards in food handling in the country, the presence of great public health hazards of *Salmonella* [22].

Food-borne diseases are also a serious threat to people in Africa, with an intolerable public health burden and causing massive economic losses. According to the most recent World Health Organization (WHO) estimates, 700 000 deaths per year in Africa are due to food and water-borne related diseases [23]. Food safety remains a critical issue with outbreaks of food borne illness resulting in substantial costs to individuals, the food industry and the economy. Despite advances in food science and technology, Food-borne infections are common public health problems, which become a significant public health issue and economic problems all over the world [24]. Therefore, the objective of this paper is to review the public health importance of *shalmonella* and associated risk factors.

2. GENERAL OVERVIEW OF SALMONELLOSIS

2.1. Historical Background

Salmonellosis is one of the most frequently reported foodborne illnesses worldwide. It was first discovered and isolated from the intestines of pigs infected with classical swine fever, by Theobald Smith in 1855. The bacterial strain was named after Dr Daniel Elmer Salmon, an American pathologist who worked with Smith. The nomenclature of *Salmonella* is controversial and still evolving. Currently, the Centers for Disease Control and Prevention (CDC) use the nomenclatural system of *Salmonella* recommended by the World Health Organization (WHO) Collaborating Centre [25].

Salmonella spp. infects a wide range of hosts including humans and can cause diseases ranging from severe enteric fever to self-limiting gastroenteritis that, in some individuals, can become systemic and life-threatening. These microbes are among the most ubiquitous organisms that cause bacterial diarrhea and can cause paratyphoid or typhoid fever, depending upon the strain [26].

2.2. Etiology

Salmonellosis is caused by *Salmonella* organism, which is a gram negative, facultative anaerobic, rod shaped, flagellated bacterium belongs to family of Enterobacteriaceae, possessing three major antigens, H or (falagellar) antigen, O or (somatic) antigen VI or (capsular) antigen overlaying the O antigen it is present in a few serovars [27]. Strains of genus *Salmonella* obey the definition of the family Enterobacteriaceae, facultatively anaerobic Gram-negative, they are straight rod usually motile with peritrichous flagella (except *S. pullorum* and *S. gallinarum*), multiply optimally at a temperature of 35°C to 37°C, pH about 6.5-7.5 and water activity between 0.94-0.84. They are also able to multiply in the environment with low level or no oxygen [28].

The bacteria are sensitive to heat and will not survive a temperature above 70°C; so it is sensitive to pasteurization, but resist to drying even for years. Especially in dried feces, dust and other dry materials such as feed and certain food [29].

2.3. General Characteristics of Salmonella

Salmonella is a rod-shaped, motile, aerobic and facultatively anaerobic, non-spore forming and Gram negative organism. It can grow from 5°C up to 47°C with an optimum at 37°C. *Salmonella* is heat sensitive and can be readily destroyed at pasteurization temperature. The infectious dose is usually greater than 10^2 to 10^3 organisms and may vary with age and health status of the host. In some cases, it can be as few as 15 to 20 cells [30].

Salmonella make up a large genus of gram-negative bacilli within the family Enterobacteriaceae and it constitute a genus of more than 2500 serotypes that are highly adapted for growth in both humans and animals and that cause a wide spectrum of disease. The growth of S. typhi and S. paratyphi is restricted to human hosts, in whom these organisms cause enteric (typhoid) fever. The remainder of *Salmonella* serotypes, referred to as non-typhoidal *Salmonella*, can colonize the gastrointestinal tracts of a broad range of animals, including mammals, reptiles, birds, and insects. More than 200 of these serotypes are pathogenic to humans, in whom they often cause gastroenteritis and can also be associated with localized infections and/or bacteremia [31].

Salmonella strains other than *S. typhi* and *S. paratyphi* are referred to as non-typhoid *Salmonella* (NTS) and are predominantly found in animal reservoirs. Non-typhoid *Salmonella* infections are characterized by gastroenteritis or an inflammatory condition of the gastrointestinal tract which is accompanied by symptoms such as non-bloody diarrhea, vomiting, nausea, headache and abdominal cramps [32] (Hohmann, 2001). *Salmonella* infection of the host often leads to a self-limiting gastroenteritis. However, the nature of the pathogenic action of *Salmonella* varies with the serovar, the strain, the infectious dose, the nature of the contaminated food and the host status [33].

S. typhi, a host-restricted human pathogen, remains an important health threat for mankind with more than 22 million cases and 220 000 deaths annually world-wide [34]. Salmonellosis is linked to the consumption of

Salmonella-contaminated food products mostly from poultry, pork and egg products. Poor hand washing and contact with infected pets are some of the contamination routes. When infective doses are ingested, the pathogen causes sickness by colonizing the intestinal tract [35].

2.4. Classification and Nomenclature

Salmonella is a Gram-negative bacterium that uses flagella for movement. The genus *Salmonella* is classified into two species *Salmonella enterica* and *Salmonella bongori*. The species *Salmonella enterica* being divided into six subspecies. *S. enterica* subsp. *enterica* (I), *S. enterica* subsp. *salamae* (II), *S. enteric* subsp. *arizonae* (IIIa), *S. enterica* subsp. *diarizonae* (IIIb), *S. enterica* subsp. *houtenae* (IV) and *S. enterica* subsp. *indica* [36]. *Salmonella enterica* subspecies I is mainly isolated from warm-blooded animals and accounts for more than 99% of clinical isolates whereas the remaining subspecies and *S. bongori* are mainly isolated from cold-blooded animals and account for less than 1% of clinical isolates. *S. typhimurium* is now designated as *Salmonella enterica* subspecies I serotype *Typhimurium*. Under the modern nomenclature system, the subspecies information is often omitted and culture is called *S. enterica* serotype *typhimurium* and in subsequent appearance, it is written as *S. typhimurium*. This system of nomenclature is used nowadays to bring uniformity in reporting [37].

Based on their association with human and animal hosts *Salmonella* can be classified into three main groups. The first group comprises *Salmonella Typhi* and *Salmonella Paratyphi* A and C, which infect only man and which spread either directly or indirectly via (food and water) from person to person [38]. The second group includes *serovars* that are host adapted for particular species of vertebrates, example *S*. gallinarum in poultry, *S. dublin* in cattle, *S. abortus* equi in horse, *S. abortus* ovis in sheep and *S. cholerae* suis and *S. typhi* suis in swine. Some of these are also pathogenic for man (especially *S*. dublin and *S*. cholerae suis). The third group contains the majority of other *Salmonella serovars* with no particular host preference that infect both animals and man. Among this third reservoir of serovars are principal agents of Salmonellosis that occurs today [39].

2.5. Pathogenesis

The ability of *Salmonella* strains to persist in the host cell is crucial for pathogenesis, as strains lacking this ability are non-virulent [40]. The virulence of *Salmonella* is related to their ability to invade host cell and resist both digestion by phagocytes and destruction by complement system. The specific O antigen is important for the virulence strain of *Salmonella* (specific antigen) by decreasing the susceptibility of phagocytosis and ability to activate the alternative complement pathway. Three toxins namely endotoxin, enterotoxin and cytotoxin play an important role in the pathogenesis of *Salmonella.* The endotoxin produce fever, the enterotoxin produce mucosal damage in the cell culture and cytotoxin inhibit protein synthesis [41]

2.6. Virulence Factors of Salmonella

2.6.1. Virulence plasmids

Not all isolates of these serotypes carry the virulence plasmid, but least six serotypes of *Salmonella* (serotypes *abortus ovis*, *cholerae suis*, *dublin, Enteritidis, gallinarum/pullorum, and typhimurium*) are known to harbor a virulence plasmid [42].

2.6.2. *Toxins*

Both of endotoxins and exotoxins can be produced by *Salmonella*. Endotoxin is the lipid portion (lipid A) of the outer membrane lipopolysaccharide of *Salmonella*, elicits a diversity of biological responses both in vivo and in vitro. The exotoxins can be subdivided in two types: the enterotoxins and the cytotoxins. Cytotoxins are defined as by their ability to kill mammalian cells. There is a significant difference in the amounts of toxin produced by either serotype [42].

2.6.3. Fimbriae

Fimbriae are diverse proteinaceous surface structures. Fimbriae are a major player in pathogenesis and a source of diversity for *Salmonella* serovars. Fimbriae are the most common adhesion systems and are differentially expressed and found in a specific pattern among each serovar [43]. The fibres are implicated in attachment to surface. Most of the *Salmonella* serovars possess 12 fimbrial gene clusters. Some fimbriae are specific to certain serovars and may play a role in these bacteria that do not need to be fulfilled in other serovars. A specific fimbrial gene cluster (FGC) encodes for the structural, assembly and sometime regulatory proteins required for the production of the filamentous adhesive appendage on the bacterial surface. However, fimbriae are implicated during infection and in a variety of other roles, like biofilm formation, seroconversion, haemagglutination, cellular invasion and macrophage interactions [44].

2.7. Salmonellosis in animals

Salmonella have a wide variety of domestic and wild animal hosts. The infection may or may not be clinically apparent. In the subclinical form, the animal may have a latent infection and harbor the pathogen in its lymph nodes or it may be a carrier and eliminate the agent in its fecal material briefly, intermittently, or persistently. In domestic animals, there are several well-known clinical enteritis due to species-adapted serotypes, such as *S. pullorum* or *S. abortus equi.* Other clinically apparent or in apparent infections are caused by serotypes with multiple hosts. Two serotypes, *S. pullorum* and *S. gallinarum*, are adapted to domestic foul. They are not very pathogenic for man, although cases of Salmonellosis caused by these serotypes have been described in children [45].

In cattle the common route of infection is ingestion of the bacteria through contaminated feed and water. It may disseminate to the rest body part of the host via the lymph fluid or blood and usually also lead to fecal excretion of bacteria. *Salmonellae* are normally inhibited by the high concentrations of volatile fatty acids and the normal pH below 7 in the rumen. These bacteria have developed mechanisms to survive and cope with the host inhibiting factors, but the normal inhibition of *Salmonella* is primarily disrupted in the rumen and small intestine when; starvation or reduced feed intake occur, the feeding strategy leads to an increased pH in the abomasum, and antibiotic treatment kills the normal competing micro flora of the intestine [46].

Severely affected animals show fever, depression, in appetence and drop in milk yield. These sign are followed by diarrhea which is foul smelling, the feces being mucoid and usually containing a clot of blood and shred of necrotic intestinal mucosa. Sign of colonic congestion of mucus membrane and dehydration may be evident. The acute disease last for about a week. *S. dublin* in particular but also other serovars may cause abortion in cows at any stage of pregnancy. Abortion may either precede the onset of dysentery or follow it within two or four weeks. Alternatively abortion may occur in cows that show no sign of illness, septicemia and/or placentitis being the case of death of fetus [47]. In calves clinical disease is most common 2-6 week of age. Clinical sign vary but typically the enteric form of diseases predominate which is characterized by pyrexia, dullness and anorexia, followed by diarrhea that may contain fibrin and mucus. The feces may become blood stained and stringy due to the presences of necrotic intestinal mucosa. Calves rapidly become weak and dehydrated unless treated. Infected calves usually die 5-7 days after the onset of disease. At this Stage the organisms have become systemic as a result of reduced innate immunity and may be isolated from variety of tissue including blood [48].

2.8. Salmonellosis in Human

Human infections of *Salmonell*a are divided into typhoid fever, caused by *Salmonella typhi* and *Salmonella paratyphi,* and also other clinical syndromes, including diarrheal disease, caused by large number of non-typhoidal *salmonella serovars.* Regarding toxins production in *Salmonella,* following ingestion of *Salmonella* cells, the pathogens invade mucosa of the small intestine, proliferate in the epithelial cells, and produce a toxin, resulting in an inflammatory reaction and fluid accumulation in the intestine. The ability of the pathogens to invade and damage the cells is attributed to the production of a thermo stable cytotoxic factor. Once inside the epithelial cells, the pathogens multiply and produce a thermo labile enterotoxin that is directly related to the secretion of fluid and electrolytes. Production of the enterotoxin is directly related to the growth rate of the pathogens [49].

Salmonella is the bacterial agent most frequently involved in cases of food borne disease all over the world. The agent is normally transmitted to humans by means of foods of animal origin, such as meat and eggs. *Salmonella typhimurium* and *Salmonella enteritidis* is the most common agent of food borne disease in humans [50]. Salmonellosis is an important global public health problem causing substantial morbidity and mortality, thus also has a significant economic impact. Although most infections cause mild to moderate self-limited disease, serious infections leading to deaths do occur [51].

Salmonellosis is most commonly caused by *S. typhimurium* or *S. enteritidis.* Secondly, *S. enterica* subsp. *typhi* and *S. enterica* subsp. *paratyphi* are the causes of typhoid fever or paratyphoid fever, respectively. *Salmonella* are the second most common pathogens isolated from humans with gastro enteric disease in developed countries. *Salmonella* penetrate the intestinal epithelium, possibly proliferating in macrophages and polymorphs, pass into mesenteric lymph nodes, liver or spleen then cause septicemia. Peritonitis and subsequent death can occur. Ulceration of the ileum can occur if organisms multiply in the bile of the gall bladder and cause re-infection. Any food could be a vehicle of infection if contaminated with human feces. Foods known to have been vehicles of typhoid fever include raw milk, shellfish and meat. However, typhoid fever is predominantly spread by water contaminated with human feces [52]. Salmonellosis is a common human intestinal disorder primarily associated with *Salmonella*-contaminated meats and poultry [53].

Infections with *Salmonella* in food-producing animals present a serious public health concern, because food products of animal origin are considered to be a significant source of human infection. Most common sources of infection are eggs and related products, and meat from poultry and other food animal species. Milk and dairy products have also been associated with outbreaks of salmonellosis in people [54]. The incubation period depends on the number of bacteria ingested and varies from 5-72 hours. Affected individuals experience sudden nausea, vomiting and watery foul smelling and diarrhea which in most cases last only a few hours [55].

More severe symptom may occur in people who are at high risk like those extreme age groups (the young because their immune system are immature and the elderly because the immune system are declining), person with decreased gastric acidity (because gastric acid is the first line of defense for the ingested *Salmonella*), person with altered gastric intestinal bacteria (including those taking broad spectrum antibiotics, purgatives or who have had bowl surgery [56]. In human infections, the four different clinical manifestations are enteric fever, gastroenteritis, bacteraemia and other extraintestinal complications, and chronic carrier state [57].

2.9. Epidemiology of Salmonella

The epidemiological patterns of prevalence of infection and incidence of disease differ greatly between geographical areas depending on climate, population density, land use, farming practices, food harvesting and processing technologies, and consumer habits. In addition, the biology of the serovars differs so widely those considerations of salmonellosis. *Salmonella* infections *or Salmonella* contamination are inevitably complex [53]. Although primarily intestinal bacteria, *Salmonella* are widespread in the environment and commonly found in farm effluents, human sewage, and in any material subject to fecal contamination. Salmonellosis has been recognized in all countries but appears to be most prevalent in areas of intensive animal husbandry, especially poultry and swine production. The epidemiology of *Salmonella* is complex largely because there are more than 2,500 distinct serotypes (serovars) with different reservoirs and diverse geographic incidences. Changes in food consumption production and distribution have led to an increasing frequency of multistate outbreaks associated with fresh produced and processed foods [58].

2.10. Geographical Distribution

S. entritidis is the most prevalent species followed by *S. typhimurium* which are a worldwide distribution. Change in the relative frequency of serotypes can be observed over a short period of time. Some times within one or two years only limited number of serotypes is isolated from man or animals in a single region or country and the predominance of one or other can vary over a time. Some serotypes like S. *entritidis* and *S. typhimurium* are found worldwide in contrast to S. *weltevreden* which seems to be confined to Asia [59].

2.11. Risk Factors Predisposing to Salmonellosis

The clinical characteristics of salmonellosis in large animals vary depending on the various management systems used, the intensity of stocking, whether or not the animals are housed, and the epidemiological characteristics of the different *Salmonella* species [53].

2.11.1. Animal risk factors

The response to infection with a *Salmonella sp*. varies depending on the size of the challenge dose and the immunological status of the animal, itself dependent on colostrum intake in neonates, previous exposure to infection and exposure to stressors, particularly in older animals [53] (Radostits *et al.,* 2007). The environmental and personal hygiene is one of the knowledge and practice restrictions of human from beef/dairy farm and abattoir food processing plants. On the other hand food getting contamination depends largely on the health status of the food handlers [60].

2.11.2. Environmental and management risk Factors

Intensification of husbandry in all species is recognized as a factor contributing significantly to an increase in the new infection rate. Any significant change in management of the herd or a group of animals can precipitate the onset of clinical salmonellosis if the infection preexists in those animals. Temperature and wetness are most important, as *salmonella* are susceptible to drying and sunlight [53].

2.11.3. Pathogen risk factors

Salmonellas are facultative intracellular organisms that survive in the phagolysosome of macrophages and can therefore evade the bactericidal effect of antibody. Compared to other organisms of the same family, *salmonellas* are relatively resistant to various environmental factors. They multiply at temperatures between 8°C and 45°C, at water activities above 0. 94 and pH range of 4-8. They are also able to multiply in an environment with a low level of or no oxygen [53].

2.11.4. Others Source

International trading and its introduction through international travel, human migration, food, animal feed and livestock trade are also other challenges; Water source: *Salmonella* can be found in contaminated water; Inanimate objects. Moreover, in recent years, antimicrobial resistance of *Salmonella* has increased worldwide, due to the widespread use of antimicrobial drugs in the human and veterinary sectors, is the other ambiguities in the food processing environment [61].

2.12. Source of Infection and Mode of Transmission

Salmonella are spread by direct or indirect means. Infected animals are the source of the organisms they excrete them and infect other animals, directly or indirectly by contamination of the environment, primarily feed and water supplies. The farm animal may be infected in different ways: by animal-to-animal transmission, especially of host-adapted serovars by contaminated animal feed and by a contaminated environment (soil, birds, rodents, insects, water supplies[53] Consumption of raw milk or inadequately pasteurized milk, improperly cooked beef from culled dairy cattle, contaminated water and direct animal contact are the major routes of acquiring dairy associated salmonellosis in humans [62].

Person to person spread has been demonstrated on many occasions and may take place in young children and group living under poor socioeconomic condition where effective sanitation is lacking. Person to person spread also may occur in hospitals, nursing homes, mental institution in which large number of outbreak has occurred. Amplification of infection in these institutions may occur from contaminated food or asymptomatic carrier's babies being at special risk [63]. Fecal oral route and vehicle born infection may result from ingestion of food or water that have been contaminated with human or animal feces or from direct exposure to animals or their waste. A lower infectious dose of organism is usually required in the elderly, the immune compromised, antibiotic users and those with achlorhydria/absence of hydrochloric acid from the gastric juice or regular use of antacid and related medication [64].

Animal may occasionally, excrete the organisms in milk during the febrile stage of the disease or more likely infected feces, from either a clinically infected cow or healthy carrier may contaminate the milk during the milking process. Milk also may be contaminated from use of polluted water from dirty equipment or from dairy workers. Indirect contamination also has been described when cattle have become contaminated with *Salmonella*. Contamination of food also may occur directly from *Salmonella* infected food handlers or indirectly from sewage polluted water [65]. Feed, water, pasture, wastes; wild animals, etc. can serve for the transmission of the pathogen *Salmonella* into farm animals which in turn serve as a source for human infection. The infection can be animal-animal, environment-animal, animal-human, and human-human [66].

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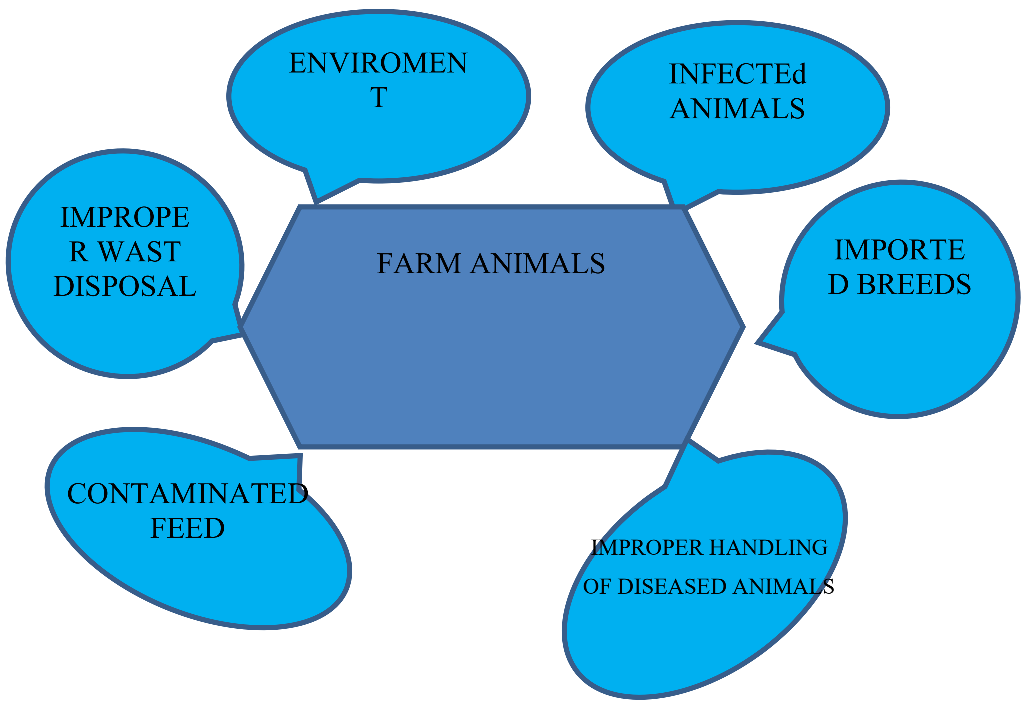

Figure 1. Figurative representation of *Salmonella spp*. indicating the source of infection and modes of transmission [66].

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2.13. Diagnosis

The clinical sign and finding at postmortem examination are not unique to salmonellosis although a tentative diagnosis may be made. They should confirm either in diseased animal or at necropsy by isolation of organisms in their feces and determination of viable counts. Fecal samples rather than swabs should be taken and these should obviously be obtained before administration of antibiotics. It may be also possible to isolate organism from oral secretion and by blood culture although these are less reliable than feces culture and must be taken with care to avoid contamination. Animal that died of salmonellosis usually have large number of *Salmonella* distributed throughout their tissue and sample of spleen, liver, hepatic, mediastinal and bronchial lymph nodes may yield count in excess of 10^6 organisms/gram. Similar concentration may be present in the wall and content of the ileum, cecum, and colon and associated lymph nodes [67].

2.13.1. Culture Methods

The traditional *Salmonella* culture method involves pre-enrichment, selective enrichment, isolation of pure culture, biochemical screening and serological confirmation, which requires 5-7 days to complete. The USDA and FDA recommended method involves a 6-24 h pre enrichment step in a nonselective broth such as lactose broth, tryptic soy broth, nutrient broth, skim milk, or buffered peptone water with a recommended incubation temperature of 37°C. Biochemical testing is done using triple sugar iron agar and lysine iron agar, which requires an additional 4–24 hours [68] .

***2.13.2**. Detection of antibodies by enzyme immunoassay (EIA)*

The detection of antibodies to *Salmonella* by EIA offers a sensitive and cost effective method for mass screening of animal herds for indications of a past/present *Salmonella* infection. The advantage of this method is that it can be automated and no incubation is required to increase the numbers of bacterial cells. The well-established technique for assaying antigens is EIA. Antibodies labeled with an enzyme are bound to *Salmonella* antigens, and the level of antigen present is determined by enzymatic conversion of a substrate, usually resulting in a color change which can be read visually or by a spectrophotometer. Serological test, such as ELISA, serum agglutination and complement fixation can be used for the retrospective diagnosis of salmonellosis or the detection of carriers [64].

***2.13.3**. Molecular assays*

Nucleic acid amplification methods have the potential to amplify small numbers of organisms and non culturable bacteria, as well as dead organisms. Real-time quantitative polymerase chain reaction (RTQ-PCR), Real Time Polymerase chain (RT-PCR), and Nucleic Acid Sequence-Based Amplification (NASBA) is used for detection of *Salmonella* from various food matrices [69].

2.14. Treatment

Treatment of non-typhoidal *Salmonella* infection is different from typhoidal infection. In treatment of non-typhoidal *Salmonella* infection antibiotics should not be used routinely, as used in typhoid. Antibiotic should be only used if required as most infection with non-typhoid *Salmonella* is self-limiting type and duration of diarrhea and fever are not much affected by use of antibiotics. Additionally antibiotic therapy can increase relapse of infection and also prolong the duration of gastrointestinal carrier states. The main treatment should be aimed at correcting dehydration that may arise due to prolonged diarrhea by fluid and electrolyte replacement [64].

Although *salmonella* are usually sensitive in vitro to many antibiotics, their use for treatment of uncomplicated gastroenteritis until recently has been generally contraindicated by their lack of favorable effect on the course of the disease and by prolongation of *Salmonella* shedding. In case of patient with bacteremia and other complication antimicrobials are used. Like-wise the treatment of enteric fever necessitates the use of antimicrobial drugs with chloramphenicol, ampicillin, amoxicillin, trimethoprim-sulfamethoxazole and newer fluoroquinoazoles being drug of choice against sensitive *Salmonella*. Proper management of fluid and electrolyte balance is important in all patients with *Salmonella* gastroenteritis but is crucial in young children and elder individuals [70].

In animal supportive treatment with intravenous fluid is necessary for patients that have anorexia, depression, significant dehydration. Oral fluid and electrolyte may be somewhat helpful and much cheaper than IV fluid for cattle demand to be mildly or moderately dehydrated. The effectiveness of oral fluid may be somewhat compromised by mal absorption and mal digestion in salmonellosis patient but still should be considered useful. Cattle that are willing to drink can have specific electrolyte (NaCl, KCl) added to drinking water to help correcting electrolyte [71] . Treatment consists of controlling the infection with effective antibiotics, and maintaining fluid balance with electrolytes. Although many cases with salmonellosis recover without antimicrobial therapy, those with severe infections may require treatment [72].

2.15. Prevention and Control

Contaminated water or food is the major transmission route of enteric fever. Historically, the USA and Western Europe were endemic for enteric fever; however, the incidence of *Salmonella* infection decreased significantly with proper food and water sanitation, pasteurization of milk and other dairy products, and elimination of the use of human feces in food production [73]. At present, preventive measures for enteric fever concentrate on access to safe water and food, proper sanitation and the use of typhoid vaccines. Ensuring the safety of water for consumption is the main goal for the elimination of possible transmission routes of typhoid *Salmonella* as well as non typoid *salmonella* (NTS). This important measure has been successfully achieved in industrialized countries, such as in Europe and the USA, but not in developing and underdeveloped countries [74].

Besides water, *Salmonella spp.* can be found in a variety of foods, predominantly in poultry, eggs and dairy products. Proper handling and cooking of food are measures proposed to eradicate the bacterial contamination of food. In many countries, food irradiation has been greatly promoted owing to its effectiveness in reducing the risk of food contamination [75]. People should not eat raw or uncooked meat, they should not drink raw milk or unpasteurized dairy product, cross contamination of food should be avoided. Uncooked meat should be kept separate from cooked food ready to eat. Hands, cutting boards or knifes and other utensils should be washed thoroughly after handling uncooked food. Hands should be washed before handling any food and in between handling different food items. People should have to wash their hands after contact with animal's feces [76].

Pasteurization of milk and treating municipals water supply for reducing risk of *Salmonella* infection, improvement in farm animal hygiene in slaughter process in food harvesting and in packaging operation has helped to prevent salmonellosis [77]. Ensuring safe food production requires knowledge on the nature and origin of animal, animal feed, the health status of animals at the farm, the use of veterinary medicinal data regarding anti mortem and postmortem findings and the risk association with post harvests production strategies [78].

2.16. Economic Importance of Salmonellosis

Salmonellosis is a significant cause of economic loss in human and animals because of the cost of clinical disease which includes, diagnosis, and treatment of clinical cases, diagnostic laboratory cost, the cost of cleaning and disinfection, and cost of control and prevention finally death. Also, when the disease is diagnosed in the herd, it can create a considerable apprehension in the producer because of difficulty in identifying infected animals [79]. Estimated annual costs for salmonellosis have ranged from billions of dollars in the United States to hundreds to millions of dollars in Canada and millions of pounds in the United Kingdom. Analysis of five *Salmonella* outbreaks due to manufactured food in North America gave direct cost of more than $36,400-$62 million [53].

Late-term abortion, mortality in ewes, and high mortality in calf can lead to extensive economic losses in sheep operations, making *Salmonella* abortion one of the economically most important diseases of small ruminants [80] (Rushton, 2009). The number of deaths from foodborne diseases like salmonellosis is likely to be underestimated as most estimates of mortality are short term and do not consider coexisting illnesses. Infections with *Salmonella* were associated with increased long-term mortality [81]. Infections with the host-adapted serotype Gallinarum biovars and Pullorum, however, cause severe disease with high mortality and immense economic losses on chicken and turkey farms [82]. *Salmonella* infection is one of the most important global poultry diseases in avian species because of its huge economic impact, worldwide distribution and difficulty posed in the control of the disease [83].

Among this *S. pullorum* is the main cause of considerable economic importance in the poultry industry, particularly in developing countries. The pathogen not only can cause high mortality rates among young chicks but also persists for a long period in the spleen and the reproductive tract, leading to the infection of eggs or progeny [84]. A great economic loss, due to this disease is that it causes high mortality rates which can reach up to 100%, decrease in production (eggs and chicks), condemnation of affected carcass and cost of medication both in humans and animals. Direct health costs such as hospitalization, consulting a physician and laboratory testing as well as the costs of lost labor in relation to a case of salmonellosis are estimated as part of a multidisciplinary task [85]. Eradication of the carrier parent flocks and grow out chicken and there placement by new chicken also cause significant economic loss [82].

Exportable eggs and meat of chickens must be free from *Salmonella*. That cause great effect on currency of one country getting from the sector [86]. It remains a serious economic problem to livestock in countries where measures of control are not efficient or in those where the climatic conditions are favors for spread of these microorganisms [87]. Financial costs are not only associated with investigation, treatment and prevention of human illness but may affect the chain of production. Contamination with *Salmonella* in poultry products can occur at multiple steps along the food chain, which includes production, processing, distribution, retail marketing, handling and preparation [88].

3. STATUS OF SALMONELLOSIS IN ETHIOPIA

In Ethiopia, there is no *Salmonella* serotype and antimicrobial resistance surveillance and monitoring system. Therefore the available information are fragmented and made available through individual publications. One study, conducted on chicken and different chicken products in Ethiopia indicated the presence of different serotypes of *Salmonella* [89]. In that study out of the total 80 *Salmonella* isolates, 8 different serotypes were identified of which *Salmonella braenderup* was the most frequent followed by *S. typhimurium var. copenhagen*, *Salmonella anatum*, *Salmonella kottbus* and *Salmonella typhimurium*. Other serotypes isolated include *Salmonella bovismorbificans*, *Salmonella hadar* and *Salmonella infantis*. *S. braenderup*, *S. anatum* and *Salmonella newport* appear to be the major *Salmonella* serotypes associated with chicken meat and chicken meat products around Addis Ababa [90].

Furthermore, studies showed that the widespread occurrence and distribution of *Salmonella* in Ethiopia. In recent years the number of out breaks of *Salmonella* in humans has increased considerably in the country. Much more is known now about the extent of foodborne illness and how severe it can be, not just in terms of acute illness, but also in terms of long term consequences. Studies indicated various percentages of *Salmonella* isolates in towns of Ethiopia. Moreover, high percentages of *S. typhi* isolates have been found to be resistant for antimicrobial agents [91].

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 locally as "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 indicate, in addition to the poor hygienic standards in food handling in the country, the presence of great public health hazards of *Salmonella* [92].

Food borne diseases are public health problems both in developed and developing countries. Thousands of millions of people fall ill and may die as a result of eating unsafe food [93]. Biological contaminants largely bacteria, constitute the major cause of food borne diseases [94].

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 [95]. In addition, the very young, elderly and immune compromised individuals are particularly more susceptible to *Salmonella* infections at a lower infective dose than healthy adults. This is more important in developing countries such as Ethiopia [96]. Nevertheless *Salmonella* populations in different geographical areas or different hosts and environmental niche may undergo different evolutionary change, due to centralization of food production and distribution and population movement [97]. A number of studies conducted by different individuals on various slaughtered beef animals and foods of beef origin are showed the prevalence of *Salmonella* in the country as indicated in the Table-1-below.

Table 1: The prevalence of *Salmonell*a studied in different Areas at Different Times of Ethiopia

Area	Species	Sample type	Prevalence	Year	Authors
Adis Abeba and Modjo	sheep and goat	Faeces, mesenteric lymph nodes, liver, spleen, and abdominal and diaphragmatic muscle.	1.80%	2003/2004	[98]
Modjo	Sheep and Goats	Skin swabs, mesenteric Lymph nodes, hand swabs,caecal contents, swabs, carcass and water	8.90%	2007/2008	[99]
Addis Ababa	Cattle	Faecaes and milk	10.76%	2010	[100]
Addis Ababa abattoir enterprise	Sheep and Goats	Liver, kidney, spleen carcass, mesenteric lymph node and feces	1.04%	2010/2011	[101]
Gondar	Cattle	Raw meat and swab	17.30%	2013	[102]
Asella	Cattle	Carcass swab, hanging material swab, Knife swab, hand swab, lymph node, feces and milk	6.50%	2014	[103]
Holeta	Dog	Rectal swab	17.10%	2015/2016	[104]
Dessie	cattle	Meat and Eviscerated knife	4.95%	2014/2015	[105]
Bahir Dar	Cattle	Meat	70%	2015	[106]
Eastern Hararghe	Cattle,Sheep and goat	Faeces	5.07%	2015/2016	[107]
Wolaita Sodo	Cattle	Abdomen, thorax, crutch and breast	12.50%	2015/2016	[108]
Ambo	Cattle	Mesenteric lymph nodes and feces	8%	2015/2016	[109]
Gondar	Animal- origin food items	Raw meat minced meat, burger, raw eggs, and raw milk	5.50%	2014/2015	[110]

4. CONCLUSION AND RECOMMENDATION

Salmonella is a leading cause of foodborne disease in human and consumption of both meat and milk has been implicated in salmonellosis outbreaks of people. Having animals and raw products it is not possible to be free from zoonotic agent; however the occurrences can be minimized by applying high standard of hygiene in all steps of the food production. Infected animals can present with a great variety of clinical symptoms, and risk factors for transmission to humans clearly differ by animal species, age groups, animal purpose and geographic region. Human salmonellosis around the globe and these outbreaks have been linked with consumption of *Salmonella*-contaminated foods of animal origins such as poultry and related derived products, pork, cattle, sheep, goats etc. Animals are a primary reservoir for non typhoidal salmonellae associated with human infections and contact with animal feces either directly through animal handling or manure or indirectly through fecal contamination of foods are principal vehicles of human infection. Finally, implementing basic and applied research to the agent that cause foodborne salmonellosis will be a crucial point for new approaches to prevent and control the disease. Reducing *Salmonella* prevalence requires a multi hurdle approach at all stages of breeding, hatching, growth, transportation and processing. Therefore additional measures to control secondary contamination could implemented, by prevention of contamination by cleaning, disinfection and hygiene of personnel; strict hygiene of the slaughter house and lairage and people should not drink unpasteurized milk or milk products and should not eat raw meat and education of food handlers and sanitary examination of the product and collaboration between government agencies, professional organizations and special interest groups are the best way to prevent salmonellosis.

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