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Animals and Food of Animal Origin as a Potential Source of Salmonellosis: A Review of the Epidemiology, Laboratory Diagnosis, Economic Impact and Public Health Significance

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Abstract Salmonellosis is an infectious disease of humans and animals caused frequently by two species of *Salmonella* (*Salmonella enterica*, and *Salmonella bongori*). Although primarily an intestinal bacterium, *Salmonella*e are widespread in the environment and are commonly found in farm effluents, human sewage and in any material that is subjected to fecal contamination. *Salmonella* cause diarrheal and systemic infections in humans. The infection most commonly results due to the consumption of food originating from animals and the environment. Studies have attributed that the subclinical infection in farm animals may lead to the contamination of meat, eggs, and milk or cause secondary contamination of fruits and vegetables that have been fertilized or irrigated with water containing fecal wastes. Salmonellosis causes significant economic loss in the management of farm animals. This can be attributed to the cost associated with the diagnosis and to treat the disease, the cost of cleaning and disinfection, and the cost of control and prevention. Moreover, emerging antimicrobial resistance can increase morbidity, mortality, and costs associated with disease management. Salmonellosis has both the social and economic consequences that require strong scientific and public health efforts to improve the situation. Because of the financial constraints, serological tests are conducted on a statistically representative sample of the population where the results are not always indicative of active infection in the herd. Enzyme-linked immunosorbent assays are available for some serovars of *Salmonella* and may be used for serological diagnosis and surveillance, especially in poultry and pigs. Vaccination, herd immunity, and antigenic cross-reactivity may compromise the diagnostic value of serological tests. Many inactivated vaccines are used against salmonellosis and some live vaccines are available commercially. Owing to the low efficacy of inactivated vaccines, oil or aluminum hydroxide adjuvants are used to improve their immunogenic properties. There is no vaccine to prevent salmonellosis in adults, whereas, a vaccine against *Salmonella typhi* has been developed, which is in use especially in children, but is only 60% effective. Prevention strategies include maintenance of sanitary/hygienic conditions in food processing plants, avoidance of cross-contamination of food, proper refrigeration of food, the supply of *Salmonella* free feed to animals, a strict inspection of meat originating from animals, detection and exclusion of carriers from food handling, and personal hygiene. Awareness should be created among the public about the risks associated with the consumption of raw meat, unpasteurized milk, smoked fish, un-cleaned vegetables, and contaminated water. This review attempts to highlight the role of farm animals in the transmission of salmonellosis, its epidemiology, laboratory diagnosis, economic impact, and public health significance.

Keywords: *antimicrobial resistance, economic, food animal, public health, Salmonellosis, zoonotic implications*

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1. Introduction

Foodborne diseases are among the most prevalent global public health problems of recent times, and their implication in health and economy is increasingly recognized [1,2,3]. These diseases are attributed to a wide range of pathogens and their toxins. Salmonellosis, the infectious disease caused by the *Salmonella* (*S.*) species (spp.) is a leading cause of foodborne illness throughout the world [4,5,6,7,8]. According to the World Health Organization (WHO) report of 1995, 88% of all foodborne diseases were caused by *Salmonella* spp. [9]. *Salmonella* is a genus under the family of *Enterobacteriaceae*, which consists of rod-shaped, Gram-negative, oxidase negative, non-spore forming, predominantly motile (peritrichous) bacteria measuring approximately 0.7 to 1.5 μm wide and 2.0 to 5.0 μm in length [10]. Salmonellosis is a common intestinal illness caused by several *Salmonella* serovars and is manifested clinically in animals and humans [11,12]. It presents as an acute or chronic enteritis, and septicemia and may cause subclinical infections [13,14].

Outbreaks of salmonellosis have been frequently reported and the disease incidence within the past 25 years has shown an increasing trend in many continents. Salmonellosis appears to be most prevalent in the areas of intensive animal husbandry, especially of poultry or pigs and dairy cattle reared in confinement [15,16]. There are reports of pandemics caused by *Salmonella enteritidis* and *Salmonella typhimurium* DT 104 in farm animals, which resulted in enacting regulations in many countries to control the prevalence of salmonellosis and to prevent foodborne infections [17].

The major drawback in the control and prevention of salmonellosis is the occurrence of clinically normal carriers in all the host species. Food of animal origin, particularly meat, poultry, and, in some instances, unpasteurized egg products are considered to be the primary sources of human salmonellosis [2,4,5,13,17,18]. Most of these food products, e.g. beef, mutton, and poultry, become contaminated during slaughter and processing, from exposure to water contaminated with the gut contents of healthy carrier animals.

The resistant organisms may act as donors of resistance determinants (genes coding for resistance) to other facultative pathogens present as human/animal commensal flora of intestinal tract which may later be associated with the disease [19].

There are more than 2500 different *Salmonella* serotypes, and all are considered potentially pathogenic to humans [20]. The non-typhoidal *Salmonella* is diverse and adapt to different hosts (unlike many S. *enterica* serotypes which were noted to be host-restricted) and are noted to cause invasive infections in humans [21].

Salmonella is a frequent cause of bacterial gastroenteritis in humans. *Salmonella* food poisoning was estimated to contribute to 1,000 deaths each year in the United States of America (USA) [22]. The economic losses associated with human salmonellosis is due to the cost associated with the laboratory investigations, treatment, and prevention of illness [23]. In this review paper, we attempt to summarize the available epidemiological information on salmonellosis in farm animals, laboratory diagnosis, economic impact and the public health significance of salmonellosis.

2. Epidemiology

2.1. Etiology

Salmonella spp. are members of the family *Enterobacteriaceae*. They are gram-negative, facultatively anaerobic bacteria. *Salmonella* spp. are classified into various serovars (serotypes) based on the presence of lipopolysaccharide (O), flagellar protein (H), and sometimes the capsular (Vi) antigens. There are more than 2500 known serovars, and it was noted that within the serovar, there may be strains that differ in virulence [24].

A few *Salmonella* spp. are host restricted, and such serovars cause disease in a limited number of animal species. These include the *S. abortusequi* (horses), *S. gallinarum* (poultry), *S. pullorum* (poultry), *S. typhisuis* (swine), and *S. abortusovis* (sheep) [25]. The genus *Salmonella* consists of two species causing frequent human infections, *S. enterica* and *S. bongori*. *S. enterica* is further divided into six sub spp. named *S. enterica* sub spp. *enterica*, *S. enterica* sub spp. *Salamae*, *S. enterica* sub spp. *arizonae*, *S. enterica* sub spp. *diarizona*, *S. enterica* sub spp. *houtenae*, and *S. enterica* sub spp. *indica* [26].

2.2. Salmonellosis in Farm Animals

The epidemiology of *Salmonella* is complex because of the prevalence of numerous serotypes which is responsible for the difficulties in controlling the disease. Epidemiological patterns of the prevalence of infection and incidences of disease differ greatly between geographical areas. Prevalence depends on the climate, population density, land use farming practices, food harvesting and processing technologies and consumer habits. Besides, the biology of each serovar differs so widely that *Salmonella* infection or its contamination/transmission is invariably complex [27].

2.3. Geographical Distribution

A previous study reported from Austria which evaluated the gastrointestinal tract and the associated lymph nodes in 100 sheep and an equal number of cattle found that 43% of sheep and 77% of cattle were infected with *Salmonella* [28]. This study had noted that 70% of the infected animals were found to harbor more than ten serotypes of *Salmonella*. The study also observed that the infection is positively correlated with the time spent by the animals at the slaughterhouse. Another study reported from Nigeria which examined 215 samples of goats noted that 7.4% were positive for *Salmonella* [29]. A study from Ethiopia which included 47 sheep and 60 goats observed a *Salmonella* prevalence rate of 6.4% and 16.7% respectively [30]. Among the *Salmonella* species, the *Salmonella enteritidis* is the most prevalent species followed by *S. typhimurium*, and both are worldwide in distribution. Change in the relative frequency of serotypes can be observed over a short period, which may not always be constant. An only a limited number of serotypes may be isolated from man or animals in a single region or country and the predominance of one or other can vary over time, which may range from a year to two years. Some serotypes like *S. enteritidis* and *S. typhimurium* are found worldwide in contrast to *S. weltevreden,* which appears to be confined to Asia [13]. A previous report had found that the serovars' *Newport, Anatum* and *Eastbourne* to be the most prevalent in Ethiopia [31].

The rate of infection in domestic animals has been estimated between 1-3%. In 1980, 16274 strains of 183 serotypes of *Salmonella* were isolated in the united states of America (USA) from the samples of meat obtained from slaughterhouses. In another examination of animals, 4.59% of positive cultures were obtained. The food from animal origin constitutes the most important source of non-typhoid salmonellosis, and information is scarce from developing countries in this regard [13].

Some previous research studies have indicated that salmonellosis is an important disease of dromedary calves and poultry in Ethiopia. A 19.8% average mortality rate inflicted by the *Salmonella* in commercial poultry farms and a 19.0% contamination rate of retailed food (chicken and minced beef) by *Salmonella* in Addis Ababa was previously reported [32,33].

Salmonella *concord* and S. *typhimurium* were the first and third-ranking non-typhoid salmonellosis (NTS) isolated from patients. In a global analysis of reports from 26 countries, S. *enteritidis* (65%) *and* S. *typhimurium* (12%) were the dominant serotypes isolated from poultry [34]. In Ethiopia, S. *enteritidis* accounted for 1.8% of the isolates and less than five isolates were from the samples of cattle, sheep, pigs, and chicken [33,35,36,37,38,39,40]. The differences in the preponderance of serovars across countries could be due to the variations in the epidemiology of the serotypes that may involve animal as well as environmental factors [33].

In a recent study from Ethiopia, the authors have assessed the prevalence and serotype diversity of *Salmonella* among the cattle. The study included the observation of salmonellosis among cattle from 29 countries and six continents. The study revealed an overall salmonellosis prevalence of 9%. The results of the study had also noted increased heterogeneity among the *Salmonella* serotypes (143 serotypes) found in different geographic regions; Africa revealing the highest heterogeneity (76 serotypes). The study noted that 10 serotypes (*S. Montevideo* and *S. Dublin* are frequent in North America and Europe, *S. typhymurium* in Africa, Asia, and Australia, other serotypes, *Kentucky*, *Meleagridis*, *Cerro*, *Senftenberg*, *Anatum*, *Mbandaka*, and *Newport*) were more common (65%). The study observed that among the frequent serotypes the *Montevideo*, *Typhimurium*, *Anatum*, *Mbandaka*, and *Newport* were found associated with human infections [41].

2.4. Modes of Transmission and Sources of Infection

The most common route of infection is feco-oral transmission. Infection with *Salmonella* can occur from dam to calf or from a contaminated environment, including, less commonly, contaminated water, feed or milk. Animals can also become infected via the conjunctiva or the respiratory tract, but these routes of transmission are rare [42].

Salmonella species can survive for long periods in the environment, particularly where it is wet and warm. They can be isolated from many sources including farm effluents, human sewage, and water. *Salmonella cholerasuis* has been isolated for up to 450 days from pig meat and several months from feces or fecal slurries [43].

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. Figurative representation of *Salmonella* spp**.** indicating the source of infection and modes of transmission is shown in Figure 1.

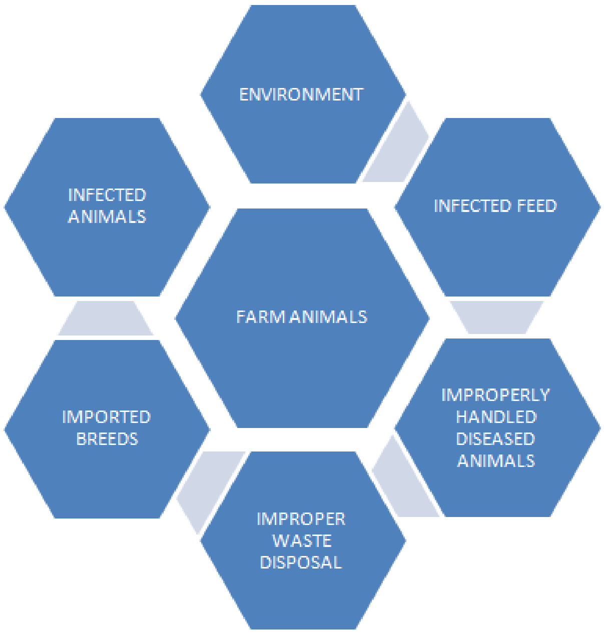

Figure 1. Figurative representation of *Salmonella* spp. indicating the source of infection and modes of transmission

2.5. Clinical Sings

Salmonellosis presents with varied clinical signs that may depend on the infecting dose, health of the host, *Salmonella* serovar/strain, and other factors. Some serovars tend to produce a particular syndrome: for example, in pigs, *Salmonella cholerasuis* is usually associated with septicemia and *Salmonella typhimurium* with the enteric disease. Although salmonellosis is seen in most domestic animals, pregnant and lactating young mammals and birds are found to be most susceptible [43].

Cattle can be chronically infected and therefore may serve as carriers within the herd and without showing any clinical signs. It has been reported that a single carrier cow can shed one billion *Salmonella*e per day through the feces. Abortion is the most common clinical consequence associated with *Salmonella Dublin* [44].

Salmonellosis in cattle may present as watery or bloody diarrhea. The other symptoms include fever, depression, anorexia, dehydration, and endotoxemia. In rare cases, the infected cattle may suffer from respiratory disease, undergo an abortion, which is associated with high mortality rates. Previous research had indicated that adult animals carry Salmonella in the form of subclinical infection, which is known to persist for months to years [45]. Such sub-clinically infected individual animals shed Salmonella intermittently, and over a variable time, the infections with host-adapted serotypes such as Salmonella *Dublin* may potentially result in clinical infection once transmitted to a susceptible host [45].

The severity of the disease and the clinical manifestations of Salmonella infection in small ruminants varies with age and the serotype [25]. Acute enteric salmonellosis is common in adult sheep which presents as fever, anorexia, depression, and diarrhea, while young animals were noted to develop septicemia [46]. However, asymptomatic carriage, chronic gastro-enteritis, and abortion have also been described [46]. Infections of ewes with serotype abortusovis were found to suffer from stillbirth, merits, placental retention, or peritonitis. The infected ewes may present with fever, anorexia, and depression before an abortion [47]. Mortality rates in the ewes were highly variable and were associated with the occurrence of secondary complications such as placental retention. It was noted that the lambs carried to full-term frequently die of post-natal septicemia [25].

In pigs, the infection with common serotypes such as *S. typhimurium* usually results in mild or no disease, and infected animals may shed Salmonella for a considerable period. For instance, piglets experimentally inoculated with Salmonella *typhimurium* developed a mild gastrointestinal disease and were found to shed bacteria in their feces for several days. Report of systemic disease and mortality associated with broad-host-range serotypes is available in the literature [48].

3. Laboratory Diagnosis

Salmonellosis can be diagnosed based on the isolation of the causative organism either from tissues collected aseptically at necropsy or from the feces, milk, blood, rectal swabs or environmental samples housing animals [13,14,15,17]. *Salmonella*e may be isolated by applying a variety of techniques, which may include using a pre-enriched non-selective medium to resuscitate sub-lethally damaged bacteria. Culture is also done by inoculating the specimens into the enrichment media that contains inhibitory substances, which suppresses the growth of non-*Salmonella* organisms belonging to the Enterobacteriaceae family [15]. Laboratory methods for the diagnosis of salmonellosis include the use of bacteriological, immunological and serological techniques.

3.1. Bacteriological Techniques

Samples are preferably collected during the acute phase of the disease or as soon as possible after the death of an infected host [49]. In the live animals, confirmation of clinical salmonellosis is performed by the culture of rectal swabs and preferably using voided feces. The organisms may be isolated by culturing blood and sometimes from the milk. At necropsy, the isolation of *Salmonella* from tissues and intestinal contents usually presents few problems, but care must be taken during the interpretation of the findings. The isolation of *Salmonella* should be correlated with the clinical signs and pathological lesions to determine the significance of the isolation [17]. The isolation and subsequent identification of *Salmonella* are dependent not only on the quality of samples but also on the culture medium and growth characteristics of the serovars, particularly those adapted to the host species [49].

3.2. Immunological and Nucleic Acid Recognition Methods

There are many alternative methods for the detection of *Salmonella*; these include the electrical conductance or impedance, immune magnetic separation (IMS), enzyme-linked immunosorbent assay (ELISA), gene probe-PCR methods, real-time PCR, quantitative PCR or microarray analysis [50,51,52]. It was observed that the available methods have not been fully validated for fecal and environmental samples and were found to be more suited to analyze food [53,54]. For DNA based methods, inhibition of the PCR reaction by elements of the test sample matrix, especially in the case of feces, is problematic and requires suitable DNA extraction techniques and controls to detect inhibition, which may reduce the sensitivity of the test in some cases [55]. Rapid isolation methodologies may also be linked with sophisticated detection systems, such as biosensors [56].

3.3. Serological Tests

Serological tests have been developed for the diagnosis of *Salmonella* infection. They are used to identify unknown cultures with known sera and may also be used to determine antibody titers in patients with unknown illnesses [49]. Slide agglutination test is one of the serological techniques used for the diagnosis of *Salmonella*. An agglutination reaction occurs when an antibody reacts with a particular antigen and cross-links 23 surface antigen determinants. A drop of polyvalent antiserum is added to a suspension of bacteria in saline followed by a control of the bacterial suspension without antiserum to rule out auto agglutination. After the addition of antiserum, the slide is rocked gently, and the result is read within after two minutes, and clumping is read as a positive reaction. Serological identification is made more precise by typing with monospecific serums [57].

4. Public Health Importance

4.1. Serovars Involved in Human Illness

More than 2,500 serovars of *S. enteric* have been identified; most have been described as the cause of human infections, but only a limited number of serovars are of public health importance. *S. enterica* serovars *Typhimurium* and *Enteritidis* have been reported to be the most common causes of human salmonellosis [58,59]. These serovars include *Choleraesuis* (predominantly in swine and human) and *Dublin* (predominantly in cattle and humans) [43,60].

Most of the isolates that cause disease in humans and other mammals belong to *S. enterica* subsp. *enterica*. A few serovars - *Salmonella* serovar. *Typhi, Salmonella* serovar. Paratyphi *Salmonella* serovar. *Hirschfeldii* are human pathogens. They are transmitted mainly from person to person and have no significant animal reservoirs. The remaining *Salmonella* serovars, sometimes referred to as non-typhoidal *Salmonella*, are zoonotic or potentially zoonotic. *S. bongori, S. enteric* subsp. *salamae, S. enteric* subsp. *arizonae, S. enteric* subsp. *diarizonae, S. enteric* subsp. *Houtenae* and *S. enteric* subsp. *Indica* are usually found in poikilotherms (including reptiles, amphibians, and fish) and in the environment. Some of these organisms are occasionally associated with human disease [43].

4.2. Occurrence in Humans

Salmonellosis occurs both in sporadic cases and outbreaks affecting a family or several hundred or thousands of people in a population [13]. The true incidences are difficult to evaluate, since many countries do not have an epidemiological surveillance system in place, and even where a system does exist, mild and sporadic cases are not usually reported. In 18 countries with a reporting system, the number of outbreaks has increased considerably in recent years which could be attributed to better reporting [13]. In the United States, the National Salmonellosis Surveillance System reporting, the level of infections was noted to decrease when compared to the data from 1996-2011 was analyzed [61]. Annual Surveillance Report from New Zealand showed, as many other country reports, varied notification rates for gastroenteritis caused by Salmonella and NTS infections [62]. The number of human Salmonella cases also seems to have declined in Tunisia based on data collected from 1994 to 2004 with the lowest isolation rate monitored in 2004 for the entire surveillance period [63]. In Africa, non-typhoid Salmonella has consistently been reported as a leading cause of bacteremia among immunocompromised people, infants and newborns [64,65]. In general, the primary sources of salmonellosis are considered to be food-producing animals, such as cattle, poultry, and swine [66]. Different studies indicated that *Salmonella* was highly prevalent in Ethiopia both in veterinary and public setups [67]. Salmonella Concord was the first ranking serovar isolated from patients. Its occurrence was higher in samples taken from children than in samples from adults [35,36].

4.3. Source of Infection and Mode of Transmission

Human salmonellosis is generally foodborne and is contracted through the consumption of contaminated food of animal origins such as meat, milk, poultry, and eggs. Dairy products including cheese and ice cream were also implicated in the outbreak [7]. However, fruits and vegetables, such as lettuce, tomatoes, cilantro, alfalfa-sprouts, and almonds have also been implicated in the outbreak [68]. More than 90% of human infections could be attributed to food contamination [69].

Person to person spread has been demonstrated on many occasions and may take place in young children and group living under the poor socioeconomic condition where effective sanitation is lacking. Person to person spread also may occur in hospitals, nursing homes, a mental institution in which a large number of outbreaks has occurred. Amplification of infection in these institutions may occur from contaminated food or asymptomatic carrier's babies being at special risk [68]. Direct or indirect contact with animals colonized with *Salmonella* is another source of infection, including contact during visits to petting zoos and farms [70].

Fecal oral route and vehicle born infection may result from the ingestion of food or water that have been contaminated with human or animal feces or from direct exposure to animals or their waste. The commonly recognized vehicle of transmission includes inadequately cooked or raw meat, unpasteurized milk or milk product, contaminated and inadequately treated drinking water. The contamination of milk may occur by a variety of routes. The 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 the use of polluted water from dirty equipment or 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 [70].

Several people raise chickens and other poultry in their backyards for meat, egg production or as a pet. In addition to household exposure, human cases have been linked to poultry contact on farms, in agricultural feed stores, and at county fairs. Young hatchlings pose a particularly high risk for humans and remarkably often infect children [71].

4.4. Clinical Feature

The outcomes of exposure to non-typhoidal *Salmonella* spp. can range from no effect on the colonization of the gastrointestinal tract without symptoms of illness (asymptomatic infection), or colonization with the typical symptoms of acute gastroenteritis [72,73]. Gastroenteritis symptoms are generally mild and may include abdominal cramps, nausea, diarrhea, mild fever, vomiting, dehydration, headache and/or prostration [7,14]. The incubation period is 8–72 hours (usually 24–48 hours) and symptoms last for 2–7 days [72,73].

Severe disease such as septicemia sometimes develops, predominantly in immunocompromised individuals. This occurs when *Salmonella* spp. Enter the bloodstream, leading to symptoms such as high fever, lethargy, abdominal and chest pain, chills and anorexia; and can be fatal. A small number of individuals develop a chronic condition or squeal such as arthritis, appendicitis, meningitis or pneumonia as a consequence of infection [12,72,74].

4.5. Treatment and Antibiotic Resistance

The use of antibiotics for *Salmonella* enteritis without septicemia (bacteremia) is controversial. The population of normal intestinal bacterial microflora may be altered and may also result in the possible development of antibiotic resistance by *Salmonella* organisms [44].

Supportive treatment with intravenous fluid is necessary for patients who have anorexia, depression and significant dehydration. Individual patients may be treated aggressively following acid-base and electrolyte assessment. The effectiveness of oral fluids may be somewhat compromised by malabsorption and maldigestion noted in salmonellosis patients, but still should be considered useful. Cattle that are willing to drink can have specific electrolyte (NaCl, KCl) added to drinking water to help to correct electrolyte imbalance [75].

Antimicrobial treatment is not routinely recommended for empiric treatment of gastrointestinal infections caused by NTS in healthy people as the infection often is self-limiting. Antimicrobial treatment should be given to patients with severe illness, immune suppression or patients suffering from bacteremia [12]. Treatment with first-line antimicrobials should include ampicillin, chloramphenicol or trimethoprim-sulfamethoxazole [12,76]. The choice differs by region and chloramphenicol is not used in most developed countries but is common in developing countries. Ampicillin and trimethoprim-sulfamethoxazole are good choices, but many do not even consider them and instead choose fluoroquinolone or 3rd generation cephalosporin [12,76].

Antimicrobial resistance can increase morbidity, mortality, and costs associated with the disease. Moreover, it has social and economic consequences and requires strong scientific and public health efforts to improve the situation. The increase in the number of resistant and multidrug-resistant (resistant to two and more antimicrobials) strains of bacteria has been recognized by the World Health Organization (WHO) and health authorities as one of the major problems in public health [77]. The use of antibiotics in food animal production systems has resulted in the emergence of antibiotic-resistant zoonotic bacteria that can be transmitted to humans through the food chain [78].

Unfortunately, the recent increased development of resistance to many antimicrobials often leaves the GP (general practitioner) with no alternative than to treat the infection with either a fluoroquinolone or 3rdgeneration cephalosporins. These antimicrobials are routinely used for empiric treatment if the susceptibility of the isolates is unknown or if the patient suffers from bacteremia [12]. For pediatric patients, treatment with a fluoroquinolone is contraindicated, and practitioners will rely on ceftriaxone or another 3rd generation cephalosporin [12].

Antimicrobial resistance can spread across the world through the epidemic spread of a particular isolate or the exchange of genetic material from one microbe to the other. The emergence of multidrug-resistant (MDR) *Salmonella* at an increasing frequency limits therapeutic options both in humans and animals [79].

The reservoir for most non-typhoid *Salmonella* in developed countries like the USA is food-producing animals, and therefore the emerging resistance in *Salmonella* is largely a consequence of the use of antimicrobial agents in animals as well as the indiscriminate prescription, and drug treatment of both human and animals [12,13,80,81].

In the developing world, nosocomial and community-acquired multidrug-resistant salmonellosis have been recurrent problems. The origins of resistance in the developing world are unknown [81]. Although the wisdom and merits of sub-therapeutic (prophylactic) and growth-promoting antibiotic regimens in animal husbandry remain a highly controversial issue, recent evidence suggests that such treatments facilitate the emergence and persistence of drug-resistant *Salmonella* strains and other foodborne bacterial pathogens in farm animals and derived meat products [16,80]. From September 2003 to February 2004, as Zewdu and Cornelius (2009) assessed antimicrobial resistance of 98 isolates of *Salmonella* serovars recovered from food in Addis Ababa, Ethiopia [82]. The prevalence and antimicrobial resistance *Salmonella* in milk and milk products were at a juvenile stage in Ethiopia. However, studies done elsewhere indicated that milk and milk products are important sources of *Salmonella* particularly among the raw milk consumers [83,84].

5. Economic Importance

Salmonellosis is a significant cause of economic loss in farm animals because of the cost of clinical disease, which includes death, diagnosis, and treatment of clinical cases, diagnostic laboratory cost, the cost of cleaning and disinfection, and cost of control and prevention. 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 [68].

Estimation of the economic impact of an outbreak of *S. Dublin* infection in the calf rearing unit indicates that the cost of disease represented a substantial proportion of the gross margin of rearing calves [68]. 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 millions. There have been few studies into the cost and benefit of preventing *Salmonella* infection, but it has been suggested that for every £1 spent on investigation and curtailment of the outbreak there is a saving of £5 [27]. Late-term abortion, mortality in ewes, and high calf mortality can lead to extensive economic losses in sheep operations, making Salmonella abortion one of the economically most important diseases of small ruminants [85]. 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 [86].

Infections with the host-adapted serotype *Gallinarum* biovars *Gallinarum* and *Pullorum*, however, cause severe disease with high mortality and immense economic losses on chicken and turkey farms [87]. A recent study had observed that agricultural production facilities could become potential reservoirs for several human pathogens [88].

6. Prevention and Control

Critical control points to decrease exposure risks in dairy cattle are: have herd sero-tested and cull carrier/infected cows, quarantine and sero-test replacement stock, isolation of sick cows, use only antimicrobials approved by a veterinarian, avoid wet areas, provide dry loafing areas, clean and disinfect calf pens and maternity area between calves, and use clean flush water. Use only water from milking parlor, check feed commodities for *Salmonella*, store and handle feed properly, control infected rodents and birds, not allow rendering trucks access to feed or animal areas, not to use front-end loaders for manure or to haul dead animals and then haul feed with them, and avoid prophylactic use of antibiotics [44].

There is no vaccine to prevent salmonellosis in adults, whereas, a vaccine against *Salmonella* typhi has been developed, especially in children, but is only 60% effective. A person who takes this vaccine would still have a strong chance of developing salmonellosis [89]. People are advised not to eat raw or uncooked meat, drink raw milk or unpasteurized dairy product, and avoid cross-contamination of food [14,90].

The control of *Salmonella* in meat animals and derived products is the most challenging task because of the complexity and interdependence of various aspects of animal husbandry, slaughtering, and food processing [16]. Because of the complexity of *Salmonella* virulence factors, little progress has been made in converting the available knowledge into therapeutics. Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), Hazard Analysis Critical Control Point (HACCP) system, appropriate food handling, and adequate water treatment remain the best preventive measures for most *Salmonella* infections [7,91,92].

7. Conclusion and Recommendations

Salmonellosis is a leading cause of foodborne disease in humans, and the consumption of both meat and milk has been implicated in salmonellosis outbreaks among people. Farming animals and handling them will predispose humans to zoonotic infectious diseases. Infected animals can present with varied clinical symptoms, and risk factors for transmission to humans differ by animal species, age groups, animal purpose, and geographic region. Besides, animals may harbor multi-drug resistant *Salmonella* species, which pose an increased public health concern when such strains are transmitted to humans.

Based on the above conclusions we recommend that a standard abattoir and personal hygiene should be employed to control contamination of meat and meat products with *Salmonella*. Awareness should be created among the public about the risks associated with the consumption of raw or undercooked meat, and other animal products. Practicing improved animal farming technologies and following better standards of hygiene during all the steps of animal breeding, and food production will minimize both animal and human salmonellosis. Antimicrobial agents must be used cautiously/judiciously used both in animals and humans.

Conflict of Interest

None.

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Nil.

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