Available online at www.scholarsresearchlibrary.com

Scholars Research Library
Annals of Experimental Biology, 2023, 11 (4): 112-123
(http://www.scholarsresearchlibrary.com)

ISSN:2348-1935

Review on Salmonella Infection in Poultry

Alamayo Nagara*

Department of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia

***Corresponding Author:** Alamayo Nagara, Department of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia*

E-mail: dhunfanagara@gmail.com

***Received:** 19 June, 2023, Manuscript no. AEB-23-103108; **Editor assigned:** 21 June, 2022, Pre QC no. AEB-23-103108 (PQ); **Reviewed:** 05 July, 2022, QC no. AEB-23-103108 (Q); **Revised:** 21 August, 2023, Manuscript no. AEB-23-103108 (R); **Published:** 28 August, 2023*

ABSTRACT

The genus Salmonella is a gram negative, rod shaped bacteria facultative anaerobe flagellated bacterium belongs to family of Enterobacteriaceae, which is one of the most common infectious agents in the tropics, especially in areas with poor hygiene. This pathogen causes the most common foodborne disease frequently isolated from food-producing animals that are responsible for zoonotic infections. Salmonella is comprised of two species, Salmonella enterica and bongori, and more than 2600 recognized serovars. However, most human salmonellosis cases are caused by relatively few serovars. Food animals, especially poultry and its products such as meat, eggs and egg products act as an important reservoir of Salmonella, which serves as a potential source of human infection and it has the ability of both vertical and horizontal transmission, which can be transmitted to humans along the farm to fork continuum. In poultry, Salmonella can cause clinical disease or subclinical infection in asymptomatic animals which are often referred to as carriers and it causes great economic losses through substantial morbidity, mortality and drop in egg production. Even when recommended biosafety measures to ensure the health of poultry flocks are in place salmonellosis outbreaks still occur globally, this challenge may be occurred due to the lack of awareness on animal health issues and due to the difficult control of this microorganism. Therefore, knowledge on the basic hygienic principles of poultry farm, occurrence and identification of the disease, the source and point of contamination has imperative for implementation of effective strategies for prevention and control of salmonellosis. The burden of pathogens in poultry multiplication centers is poorly known in Ethiopia. Thus, the aim of this review was to provide information on the importance of salmonellosis with a particular focus on Salmonella infection in poultry farms.

Keywords: Salmonella, Animals, Economics, Eggs, Micro organisms

INTRODUCTION

Poultry is the largest livestock group in the world, estimated to be about 23.39 billion, primarily consisting of chickens, ducks, and turkeys. While chicken alone reached over 1 billion and has continued to be important in the improvement of food security and livelihood contributing about 28%-30% of all animal protein consumed worldwide. The total population of chickens in Ethiopia is estimated to be about 57 million of which 95.86% are indigenous and are primarily raised by smallholder farmers in scavenging habitats. Chicken production offers considerable opportunities for generating employment, improving family nutrition, and ultimately ensuring household food security.

Even though chickens are one of the most significant sources of food for survival and have phenotypic characteristics that are appropriate for ecological, social, and cultural contexts, the country Ethiopia did not produce as much food from its chicken flock as was expected due to many factors including, infectious diseases, low input of veterinary services, poor housing, poor management, predators and, the quality and cost of feed especially infectious diseases, caused by *Salmonella* species, are one of the primary problems and public health concerns.

The genus *Salmonella* is a gram negative, rod shaped, facultative anaerobe, flagellated bacterium that belongs to the family of Enterobacteriaceae which is one of the most common infectious agents. It is comprised of two species, *Salmonella enterica* and *bongori*, and more than 2600 recognized serovars [1]. The majority of *Salmonella enterica* subspecies are found in mammals, where they account for 99% of human and warm blooded animal infections. Many of these subspecies can be carried by chickens without causing any symptoms [2]. Contrarily, the other five *Salmonella enterica* subspecies including *Salmonella bongori* are uncommon in humans since they are primarily found in the environment and cold-blooded animals [3]. In Sub-Saharan Africa, Non-Typhoidal Salmonella (NTS), mostly caused by *Salmonella Typhimurium* and *Salmonella Enteritidis*, is a major public health problem.

Food borne infectious diseases caused by the *Salmonella* pathogen, particularly in chickens, have been a major concern for global public health, and a significant amount of eggs spoil due to microbial effects, resulting in enormous economic losses through significant morbidity, mortality, and a decrease in egg production [4,5]. Although illnesses caused by this infection have been related to a wide variety of food sources, chicken and chicken products (eggs and food products containing eggs) are commonly linked to NTS and have been proven to serve as primary vehicles for human salmonellosis [6]. Chicken products like eggs are perishable, easily exposed to, and vulnerable to several pathogens such as Salmonella along the entire supply chain from their production to consumption; vertically from contaminated laying hen reproductive system, and horizontally from the environment after and during lay [7].
Due to the uncontrolled use of antimicrobials for therapeutic purposes and as additives in poultry feed, which has resulted in the emergence of multidrug resistant *Salmonella*, the emergence, and spread of antimicrobial resistance among zoonotic Salmonella have become a public health concern throughout the world, especially in developing countries). If antimicrobial usage continues at the current rate, it is predicted that antimicrobial resistance will increase, resulting in the deaths of 10 million people annually and a 2%-3.5% decline in Gross Domestic Product (GDP) [8].

Statement of the problem

Despite the safeguards already in place, *Salmonella* infection caused by contaminated chicken and its products remains a major problem, with millions of cases reported each year all over the world. Controlling salmonellosis is challenging because there are various ways that Salmonella can enter flocks and the disease has a complex epidemiology [9]. In addition, the ability of this organism to infect chicks at early age persists for a long time in the infected chickens asymptomatically and allows for vertical transmission to the progeny through contaminated eggs and stay in farm environments, allowing for its uncontrolled spread [10].

Fuche, et al. revealed that the global burden of NTS is approximately 94 million cases of NTS gastroenteritis worldwide each year, causing 155,000 fatalities. With the great expansion of poultry rearing and farming, salmonellosis has become a widespread problem in Ethiopia like in other countries of the world [11].

In Ethiopia, the prevalence of Salmonella in layer chicken farms is so little understood and the burden of pathogens in poultry farms is poorly known, which may entail the risk of distributing infected chickens unless appropriately handled. Despite being a significant zoonotic, food borne pathogen with high drug resistance as well as diversity in its strains and host ranges, there have been a few research studies on *Salmonella* infection regarding the status of antimicrobial resistance and *Salmonella* prevalence from layer chicken farms in the study area. Additionally, there is still lack of understanding concerning NTS in layer chicken at the farm level. So this review needed to be accessed and mitigate the effect of the disease in the poultry industry [12].

Objectives of the review

- To highlight about the background information of *Salmonella* infection.
- To review the importance of Salmonella infection in poultry.

LITERATURE REVIEW

Taxonomy and nomenclature

The *Salmonella* organism, which causes salmonellosis, is a gram-negative, facultatively anaerobic, rod-shaped, flagellated bacterium belonging to the Enterobacteriaceae family [13]. Theobald Smith, who lived from 1859 to 1934, was the first to characterize the Salmonella bacterium. In 1885, two American veterinarians named Salmon and Smith identified the bacterium that causes hog cholera from infected pigs [14]. Later, in honor of Dr. Salmon, the name Salmonella was selected, and it is still evolving.

The genus consists of two species: *Salmonella bongori* and *Salmonella enterica*. The species *Salmonella enterica* includes more than 2610 serovars and is a major cause of food borne illness in humans [15]. Distribution according to species and subspecies is as follows: *Salmonella enterica* subsp. *Enterica* (I) (1,547 serovars); *Salmonella enterica* subsp. salamae (II) (513 serovars); *Salmonella enterica* subsp. arizonae (IIIa) (100 serovars); *Salmonella enterica* subsp. diarizonae (IIIb) (341 serovars); *Salmonella enterica* sub sp. houtenae (IV) (73 serovars); *Salmonella enterica* subsp. indica (VI) (13 serovars); differentiated by their biochemical behavior, mainly in terms of sugar and amino acid metabolism. Salmonella bongori (23 serovars); the newly proposed species *Salmonella subterranea* was not recognized, and is considered a *Serovar* of the *Bongori* species [16].

The Kauffman and white classification system is another system in addition to the classification of subspecies based on phylogeny [17]. This scheme classifies Salmonella further into serotypes based on three major antigenic determinants including somatic (O), Capsular (K), and flagella (H) [18].

Salmonella is categorized epidemiologically based on the preferences of the host. The first group consists of host restricted serotypes, such as Salmonella typhi and Salmonella paratyphi, which only infect humans. The second group consists of host adapted serotypes, which are linked to a single host species but can infect other hosts; examples include Salmonella Dublin in cattle, *Salmonella* Abortus equi in horses, *Salmonella* Abortus ovis in sheep, and *Salmonella* Choleraesu in pigs. The third group contains the majority of other *Salmonella* serovars with no particular host preference that infects both animals and humans. The three serotypes of *Salmonella* that are typically most frequently found in human samples each year are *Salmonella Enteritidis*, *Salmonella Typhimurium*, and Salmonella Heidelberg [19].

General characteristics of salmonella

Salmonella species are common diseases that can spread to humans, livestock, wild animals, birds, and insects. They can also grow in a variety of environments without the presence of living hosts. Salmonella are facultative anaerobic bacilli that are gram negative, non-spore forming, and 2 to 3 by 0.4 m to 0.6 m in size. The majority of Salmonella serotypes grow best at temperatures between 35℃ and 37°C, however, some can also grow at temperatures as low as 2℃ to 4°C or as high as 54°C. They are heat sensitive and frequently perish at temperatures of 70°C or higher. Salmonella grow in a pH range of 4 to 9 with the optimum between 6.5 and 7.5. Complete inhibition of growth occurs at temperatures less than 7°C, and pH less than 3.8 [20].
Biochemically, *Salmonella* strains can metabolize nutrients, and catabolize D glucose and other carbohydrates, except lactose and sucrose, with the production of acid and gas. They are catalase positive and oxidase negative, like all genera in the Enterobacteriaceae family. They do not ferment malonate, do not hydrolyze urea, do not produce indole, use citrate as a sole source of carbon, reduce nitrate to nitrite, and may produce hydrogen sulfide.

Epidemiology and its geographical distribution

Salmonellosis in chicken has complicated epidemiology, which frequently makes disease control challenging. Depending on factors including temperature, population density, land use, farming methods, food harvesting and processing technology, and consumer behaviors, epidemiological patterns of infection prevalence and disease incidence differ significantly between geographical places. Furthermore, because the biology of the serovars varies so greatly, *Salmonella* infections, or *Salmonella* contamination will be complex. Despite being largely intestinal bacteria, Salmonella is ubiquitous in the environment and is frequently discovered in sewage from people and animals as well as in any object that has been exposed to feces. Salmonellosis has been recognized in all countries but appears to be most prevalent in areas of intensive animal husbandry, especially poultry and swine production.

There is a shortage of data on the main reservoirs, origins, and modes of transmission of NTS in Africa, in contrast to the situation in high income countries where food borne disease surveillance is well developed and epidemiologic investigations inform control actions. Control efforts are hampered by a shortage of epidemiologic data. In addition, Majowicz, et al. reported that 80.3 million of the 94 million NTS cases recorded were of food borne origin. The most prevalent human salmonellosis burden in Ethiopia has been linked to the epidemiologically significant NTS serotypes *Salmonella Typhimurium*, *Salmonella Enteritidis*, *Salmonella* Heidelberg, and *Salmonella* Newport, which use poultry and products derived from poultry as important reservoir sources.

Mode of transmission and predisposing factors

The Gastrointestinal Tract (GIT) of a wide range of domestic and wild animals serves as the reservoir for *Salmonella*, and a variety of foods with both animal and plant origins may infect consumers. In most cases, contamination comes from the birds themselves or by cross infection with reservoir feces, water, equipment, and workers hands during the handling of chickens. Applying manure from potentially infected or reservoir animals or humans are the primary cause of the contamination of agricultural product at the moment. As a result, *Salmonella enterica* will appear more frequently and persist longer in the intestines of feeding animals, leading to the development of chronic or asymptomatic carriers that continue to excrete the bacterium. As a result, these carriers act as reservoirs for future Salmonella contamination and dissemination through contaminated meat, eggs, and other agricultural products fertilized and grown in manure contaminated with Salmonella.

Pests including cockroaches, flies, and rodents (mice and rats) contribute significantly to the spread of *Salmonella* from one farm building or facility to another. Rodents can carry the bacteria in their digestive tracts asymptomatically and without showing any signs of clinical disease, making them important *Salmonella* carriers and reservoirs. They are frequently linked to frequent feed, water, and grain storage contamination in farms and can mostly pick up germs from sick or stray animals feces. Additionally, flies serve as mechanical vectors that help the bacterium spread from farm to farm and from poultry to humans, according to reported cases. Farm animals become ill when they consume food or water that has been polluted by flies carrying the *Salmonella* bacteria. Fly populations near poultry farms and other environments have been found to harbor Salmonella. According to Andrés, et al. wild animals including wild birds and other wildlife are significant reservoirs of Salmonella infection. A different study found a connection between the presence of visitors and Salmonella on the farm.

Transmission method of salmonella to a chicken egg: *Salmonella enteritidis* can colonize reproductive tissues (ovaries and oviducts) in infected hens, which allows it to contaminate the edible internal components of eggs (yolk or albumen). Because Salmonella may be quite persistent in the environment of poultry houses, there are numerous opportunities for hens to become exposed to it and become infected and subsequently lay eggs that are contaminated. Salmonella enters the yolk of contaminated eggs through the vitelline membrane and multiplies there because the environment is favorable for its growth. The temperature and length of storage play a major role in the vitelline membrane's integrity. The vitelline membrane becomes more permeable, releasing nutrients and iron from the albumin and inviting Salmonella species towards the egg yolk. After only 7 days to 10 days of storage at temperatures between 18°C and 30°C, the number of bacteria inside the eggs increases.

Salmonella enteritidis contamination of developing eggs can occur when various hen reproductive tracts become colonized. This can happen in the albumen, yolk, or both of the developing eggs. *Salmonella enteritidis* can rapidly and significantly multiply in the yolk contents when stored at warm temperatures, even though it is more likely to be deposited in the albumen or on the vitelline (yolk) membrane than inside the nutrient rich yolk interior.

Virulence factors

Salmonella produces a wide range of virulence determinants, some of which are components of the adhesion systems, such as adhesions, invasions, fimbriae, hemagglutinins, *Salmonella* plasmid virulence (spv), exotoxins, and endotoxins. These elements, either separately or in combination, enable Salmonella to colonize its host by adhering to it, invading it, surviving, and evading the host's defense mechanisms, including the stomach's acidity, the gastrointestinal system's proteases, as well as the host's defense mechanisms against the host's aggressions of the intestinal micro biome. The condition of the host and the bacterium affect how a Salmonella infection will turn out. The so called virulence factors, which are defined as follows, determine the bacterium's status.

Type III secretion systems: In the bacterial membrane, type III secretion systems are made up of many proteins that combine to form a spectacular organelle that resembles a needle-like structure. Specialized virulence mechanisms known as TTSS have evolved to allow the indirect translocation of bacterial virulence proteins into the cytoplasm of the host cell. Two SPIs (SPI-I and SPI-II) that each code for a TTSS has so far been identified in Salmonella species, and they may demonstrate the adaptability of this highly successful pathogen in causing various diseases.

Salmonella pathogenicity island: Salmonella pathogenicity island 2 (SPI-2) makes it easier for the bacteria to survive and reproduce inside the phagosome by preventing the entry of reactive oxygen and reactive nitrogen intermediates. However, SPI-7 is the most significant pathogenicity island in *Salmonella* typhi infection because it codes for the VI antigen that is expressed on the cell surface. The VI antigens are essential for increased virulence and severity of symptoms.

Fimbriae

Salmonella has 13 predicted fimbriae loci, many of which are induced *in vivo* and are required for biofilm formation, attachment for host cells, and colonization but not intracellular survival. The type I fimbrial adhesion FimH mediates T3SS1 independent uptake in murine dendritic cells.

Flagella and flagellin

Salmonella invasiveness can be increased by flagella-based motility, though this is still controversial, especially given how strongly innate immunity is induced by flagellin monomers. T3SS1 translocates flagellin into the cytoplasm of *Salmonella* infected macrophages, activating the inflammatory response and causing caspase-l-mediated cell death. Although it has been proposed that T3SS1 may produce flagella in macrophages and utilize them for escape, flagella are significantly suppressed inside the host.

Virulence plasmids

Plasmids frequently encode the virulence factors that make enteric bacteria pathogenic. The main *Salmonella* virulence factors are encoded by the two genes SpvB and SpvC. Both are translocated into host cells through the T3SS2. All plasmids contain the 7.8 kb Salmonella plasmid virulence (*Spv*) locus. This locus harbors five genes designated *Salmonella* plasmid virulence (*Spv*) RABCD. Expression of the *Spv* genes might play a role in the multiplication of intracellular Salmonella.

Pathogenesis

Salmonella strains must be able to survive inside the host cell to cause disease; otherwise, they are not pathogenic. *Salmonella* has an infectious dosage that ranges from 103 to 106 ppm colony forming units. This variation most likely reflects *Salmonella's* capacity to withstand the stomach's low pH, which is a potent host defense (Kemal, 2014). Salmonella is enclosed in a membrane compartment known as a vacuole, which is made of the membrane of the host cell, after being absorbed by the host cell. Normal conditions would cause the host cell's immune response to be activated by the presence of the bacterial foreign body, leading to the production of lysosomes and the secretion of digestive enzymes to destroy the intracellular bacteria. However, Salmonella modifies the compartment structure by introducing additional effector proteins into the vacuole *via* the type III secretion system. The modified vacuole prevents the lysosomes from fusing, allowing the bacteria to replicate and survive inside the host cells.

The pathogenicity of the bacteria allows them to survive with the host and then multiply inside cells, particularly macrophages, which is how *Salmonella* can invade the host. The digestive system is where germs proliferate before spreading to the intestinal mucosa, caeca tonsils, and Peyer's patches, liver, and spleen, which are the primary sites of multiplication, are affected when the Salmonella pathogen is engulfed by macrophages through the bloodstream and/or lymphatic systems. Bacteria can spread to other organs, in particular the ovary, oviduct, heart, pericardium, gizzard, yolk sac, and/or lungs, if the host's immune system is compromised. The severity and degree of the pathogenesis are dependent on three factors, infection dose, a predisposing factor that reduces the immune defense of the host, and the immunity level of the host.

Clinical signs

Both humans and animals are susceptible to Salmonella infection. While some of these infections cause disease, the majority probably lead to subclinical cases resulting in a healthy carrier state with intermittent excretion of Salmonella in feces. While a human develops disease following ingestion of Salmonella depends on the dose of the organism, the species of Salmonella, and the specific and non-specific immunological factors. Species such as *Salmonella typhimurium* and *Salmonella enteritidis* usually cause gastroenteritis (food poisoning). The majority of food poisoning outbreaks caused by Salmonella follow the consumption of food directly or indirectly associated with infection in animals. The chain of transmission is often from contaminated animal food staff to animals and then from contaminated animal products to man.

Clinical signs in poultry: Salmonellosis is an opportunistic disease that can cause spontaneous outbreaks. Its severity is based on the host's level of immunity, the virulence of the organism, and the dose of the infection. Clinical symptoms are the primary means of identifying the bacterium, but other general symptoms may be shared with other illnesses, such as lethargy, severe depression, anorexia, appearing listless, and standing with the head stuck in the neck and both eyes closed. The majority of the infected chicks had droopy wings with ruffled feathers, complete inappetence, increased thirst, and gradual weakening. In acute cases, diarrhea that ranged from watery to mucoid and greenish yellow was the most typical clinical symptom. In a few outbreaks, lameness in birds was also noted.

The pullorum disease related lesions and the fowl typhoid lesions in chicks were identical in terms of their visual appearance. The emergence of a bronze-colored liver was a noticeable and prominent lesion in typical cases of avian typhoid. At 7 to 15 days of age, the liver's bronze discoloration was more frequently seen. The damaged chicks of this age group also had numerous reddish hemorrhagic foci that were distributed uniformly across their surfaces as well as grayish necrotic foci or necrotic patches on their livers. The young chicks that died also had pale liver discoloration, liver enlargement, and liver congestion in addition to moderate gallbladder distension. Diffuse regions of necrosis were also seen in a number of these patients.

Clinical signs in humans: Humans can acquire *Salmonella* infections in a variety of ways, from self-limiting gastroenteritis typically carried on by NTS to typhoidal fever with potentially fatal intestinal perforations. With an estimated annual incidence of 1.3 billion cases and 3 million deaths, NTS is one of the main causes of food poisoning globally. Salmonellosis outbreaks have been documented for years, but over the past 25 years, the disease's prevalence has expanded throughout many continents.

Although the incubation time in persons varies, it typically lasts between 12 and 36 hours. Although vomiting is uncommon, the primary presenting symptom is typically diarrhea, which may also be accompanied by nausea and stomach pain. A headache and a fever could also be present. Although the illness is typically self-limiting and does not need antibiotic treatment, bacteremia can occasionally happen when it is caused by a more invasive strain of Salmonella.

Non-Typhoid *Salmonella* (NTS) strains are commonly referred to as Salmonella strains other than *Salmonella* typhi and *Salmonella* paratyphi, and animals are their primary reservoir for these pathogens. Gastroenteritis, a disorder that causes inflammation in the digestive tract and is associated with symptoms like bloodless diarrhea, vomiting, nausea, headaches, stomach cramps, and myalgia, is what differentiates NTS infections from other types of infections. Rarely do NTS infected patients experience symptoms like hepatomegaly and splenomegaly.

Diagnostic technique

Culture method: Although a tentative diagnosis may be made, the clinical sign and finding at the postmortem examination are not specific to salmonellosis. Salmonellosis can be diagnosed based on clinical symptoms and pathogen isolation from the feces, eggs, or blood of infected poultry. Cloacal swabs, fresh feces from live birds, intestinal contents, egg shells, egg contents, and embryos can also be used for the isolation of Salmonella. Pre-enrichment, selective enrichment, isolation and selection, biochemical test, and final identification are all steps for finding the bacterium. This method takes six to seven days to identify and confirm positive samples, and at least four days for a negative result.

Small amounts of Salmonella may be found in environmental samples, the feces of asymptomatic chicken frequently coexist with much higher concentrations of other Enterobacteriaceae or members of other families. Therefore, pre-enrichment media like buffered peptone water, nutrient broth, and tiptoes soy broth are required to assist in the isolation process. Pre-enrichment is additionally required to enable the detection of low levels of Salmonella or damaged Salmonella. Salmonella that has been sub-lethally damaged, such as by freezing, heating, exposure to antimicrobials, or evaporation, may be resurrected by pre-enrichment with non-selective broth medium for 18 h-24 h at 35°C-37°C. This allows the small numbers of Salmonella that might otherwise be killed by the toxic effect of selective enrichment media to multiply.

The inoculation of pre-enrichment broth into selective enrichment media after it has been incubated usually increases the probability of successfully isolating Salmonella. The Salmonella population is isolated from the entire organismal population using selective enrichment media. The two most crucial media for enriching *Salmonella* species are Rappaport-Vasiliadis and Muller Kauffman Tetrathionate. The culture acquired during pre-enrichment is inoculated into Rappaport-Vasiliadis medium with soya (RVS broth) and Muller-Kauffmann Tetrathionate/novobiocin broth (MKTTn broth). The MKTTn broth is incubated at 37 °C for 24 hr, while the RVS broth is incubated at 41.5°C for 24 hrs.

Bacterial cells are isolated from selective agar plates such as Hektoen Enteric Agar (HEA), Xylose Lysine Deoxy-Cholate (XLD), and/ or Brilliant Green Agar (BGA). The XLD agar is incubated at 37 °C ± 1°C and examined after 24 h ± 3 h. The second selective agar is incubated according to the manufacturer's recommendations. Brilliant Green Agar (BGA), bismuth sulfite agar, and others could be used as the second plating-out medium (ISO-6579, 2002).

Antimicrobial susceptibility test

The misuse of antibiotics in food animal production has been identified as one of the key drivers of the increasing problem of rising antimicrobial resistance among food borne microorganisms. There is evidence that extensive antibiotic use in animals used for food production may contribute to the development of drug-resistant strains. AMR in agriculture continues to be a global concern even though the use of some antimicrobials, such as chloramphenicol, in animal production has been prohibited in several regions of the world. Monitoring the incidence and prevalence of AMR in meat and livestock allows early detection, which can be used to develop measures to enhance antibiotic therapy and decrease selection pressure on resistant strains. Antimicrobial Susceptibility Testing (AST) and the identification of genes for antibiotic resistance typically achieve this.

Early in the 1960's, the first instance of *Salmonella* antibiotic resistance was noted; this resistance was to the antibiotic chloramphenicol. Since then, there has been a rise internationally in the frequency of isolation of *Salmonella* serotypes that are resistant to one or more antibiotics. This has been linked to the abuse, overuse, and widespread availability of antibiotics in many countries. *Salmonella* is thought to be the cause of 100,000 antimicrobial resistant infections per year in the United States. *Salmonella* is known to develop multidrug resistance when exposed to drugs including ampicillin, chloramphenicol, and trimethoprim-sulfamethoxazole. This is a major threat to public health because a majority of MDR Salmonella infections in humans are acquired by ingestion of contaminated foods of animal origin such as chicken and chicken products including eggs.

Antimicrobial drugs are used in veterinary medicine for treatment, prophylaxis, metaphylaxis, and growth promotion. Farmers use sub therapeutic amounts of antibiotics to diet and water to encourage the growth of poultry. This strategy makes sure everyone in the group gets the medication, but it also poses a public health risk because many resistant germs may pass their resistance to microbes found in bird feces. Due to the possibility of pathogens spreading and resistance genes being transferred *via* the food chain to pathogenic and commensal microorganisms in humans, this type of use may be held responsible for the selective pressure that leads to the development of resistant bacteria, a current, widespread public health issue. This may result in fewer treatment options for infections.

Disk diffusion: Disk diffusion is the process of diffusing a preset concentration of an antimicrobial agent from disks, tablets, or strips into a solid culture medium that has already been seeded with the chosen inoculum separated from a pure culture. The basis of disk diffusion is the determination of an inhibitory zone that is inversely correlated with the bacterial susceptibility to the antibiotic contained in the disk. A gradient of the antibiotic is produced by the antimicrobial agent's diffusion into the seeded culture media. The zone of inhibition is defined as the point at which the concentration of the antibiotic is so low that it can no longer prevent the growth of the test bacterium.

The Minimum Inhibitory Concentration (MIC) for that specific bacterial/antimicrobial combination is connected to the diameter of this zone of inhibition surrounding the antimicrobial disk; the zone of inhibition corresponds inversely with the MIC of the test bacterium. Both interpretive criteria should be included in antimicrobial ranges (susceptible, intermediate, and resistant). Generally, the lower the concentration of antimicrobial needed to prevent the growth of the organisms, the wider the zone of inhibition. But this depends on how much antibiotic is in the disk.

Prevention of *Salmonella* in poultry farms

Biosecurity: *Salmonella* infection risk in poultry farms has been observed to be reduced by biosecurity related procedures including visitors and vehicles. Enhancing efficient biosecurity procedures and management techniques in animal and poultry flocks are crucial components of a program to lower the risk of salmonellosis in the production of poultry farms. Plans should be made for intervention strategies, such as Salmonella monitoring programs along the farm to table continuum. Every biosecurity measure (management of human traffic, cleaning and sanitization of all items traveling between flocks, appropriate building location and structure) is an asset in the capacity to endure economically. Biosecurity should be viewed as an insurance premium for a more predictable future, not as an unnecessary expense.

Before the poultry building is constructed, planning for an efficient biosecurity program begins by choosing a location that is distant from other poultry farms, public roads, hatcheries, feed mills, rivers, and lakes that attract wild ducks and shorebirds. Vehicles and equipment used to transport feed, pullets, or dead hens between farms and poultry houses should also be cleaned and sanitized. The exterior of the cars, including the vehicle wells and wheels, should get special attention. Moving between chicken buildings should require both employees and visitors to wash their hands, use disinfectant footbaths, and wear clean apparel and boots. Animals such as wild birds, cats, and other wildlife should not be allowed inside poultry farms.

Rodent control: Rats and mice are the main reservoir and source of infection for laying hens and are biological vectors that can spread and increase the amount of Salmonella in chicken houses. Because food, water, and shelter are all easily accessible, rats find chicken houses to be the ideal places to dwell, and high rodent populations in chicken houses have regularly been linked to laying hens with *Salmonella* infections. *Salmonella enterica* infection is more common in laying hens on farms with high rodent densities when compared to hens on farms with low rodent densities. Even after cleaning and disinfecting the home, *Salmonella enterica* may remain in rat populations on a farm for at least 10 months. Rodent infestation and inadequate cleaning procedures have been linked to *Salmonella enterica* infection of consecutive flocks of chickens. Because they move around, mice and rats can transfer Salmonella from one flock to another, to the adjacent homes on the same property, and neighboring farms.

Minimizing environmental exposure: An important step to avoid infection of replacement pullets going into a previously infected house and the production of *Salmonella* affected eggs is the timely cleaning and disinfection of contaminated laying hen houses after the removal of spent chickens. The proportion of eggs contaminated with *Salmonella* and the related human illness is directly correlated with the extent of environmental contamination in poultry houses.

Salmonella contamination in chicken houses that have not been properly cleaned and disinfected may infect the following flocks that enter the houses, and the farm environment may be the main contributor to the infection of laying flocks. Salmonella in poultry buildings must be considerably reduced by cleaning before disinfection. The first step in disinfecting a layer hen house is to remove all eggs, dead and alive chickens, and moveable equipment to provide room for deep cleaning. Old feed that remains in hoppers, troughs, and feed bags, as well as feed that has caked-on troughs, should be removed by scraping since feed that is left within a building can offer food for insects and rats. If moist cleaning is employed, homes should be given plenty of time to completely dry before being disinfected. Houses need to be disinfected after cleaning with a high pressure spray, foam, aerosol, or fumigation. All disinfectant safety, dilution, and application directions provided by the manufacturer should be carefully followed.

Probiotics: Probiotics can be utilized to alter the gut's environment to prevent *Salmonella* from colonizing, invading, multiplying, and shedding. Young fowl, in which stable gut flora has not yet been established, are especially in need of this. These advantageous bacteria can occupy the intestine and actively compete with pathogen colonization, preventing it (or at least reducing it), by being added to feed or water. Probiotics are preparations or products that contain living, predetermined microorganisms in sufficient quantities to change the host's gastrointestinal micro flora and so have a beneficial effect on their health.

By competing for attachment sites on the luminal surface of enterocytes, competing for nutrients, and creating antibacterial substances, beneficial microorganisms in probiotics may prevent enteric infections (volatile fatty acids, low pH, and bacteriocins). Additionally, probiotic bacteria may impair pathogen metabolism by altering the activity of enzymes and enhancing or suppressing immunity by elevating antibody levels and macrophage activity.

Vaccination

Chickens are immunized using live, attenuated, and dead *Salmonella* vaccine. Although less frequently than might be anticipated in flocks that have not had vaccinations, flock illness and the generation of contaminated eggs may nevertheless happen. Although it has been demonstrated that immunization greatly reduces the number of chickens infected with *Salmonella* and the rate of egg transfer, these problems are not completely resolved. Additionally, maternal antibodies found in the yolk of infected eggs may inhibit the development of *Salmonella*. No vaccine is 100% effective, and poor Salmonella vaccine efficacy has been associated with inadequate rodent control, poor cleaning, and disinfection, a lack of feed or water, or environmental conditions like extreme heat. Infections with

Salmonella in humans have significantly decreased in the UK as a result of vaccination of laying flocks against the disease.

Following a challenge with Salmonella Infection, live vaccinations diminish intestine colonization, infection of internal organs (spleens, livers, ovaries, and oviducts), and quantities of contaminated eggs. Live vaccines promote cell mediated immunity, which is crucial for eliminating *Salmonella* from internal organs, as well as mucosal immunity in the digestive system. Live *Salmonella* vaccinations establishing attachment sites in a chick's digestive tract may prevent later *Salmonella* colonization because Salmonella strains can actively compete with one another for survival. In edible liquid egg contents, *Salmonella bacterins* may significantly reduce the amount of *Salmonella* cells. High quantities of circulating antibodies are induced by *Salmonella bacterins*, and both complete protection and opsonic action supplied by antibodies as well as immunity mediated by T cells and macrophages are required.

Treatment

Salmonella related gastroenteritis is often a self-limiting illness, with fever and diarrhea subsiding within 72 hours and 3 days-7 days, respectively. Therefore, the main goal of therapy should be to replace fluid and electrolyte losses. Antimicrobials should not be routinely used to treat NTS gastroenteritis that is not complex or to lower convalescent stool excretion. However, any systemic illness should be thought about receiving antibiotic medication (Kasper, 2005). At high levels, antibiotics help to prevent disease in exposed animals and to treat diseases. For the treatment of salmonellosis gentamicin (22.22%), neomycin (17.28%), oxytetracycline (11.11%), amoxicillin (6.17%), enrofloxacin (25.93%) and ciprofloxacin (17.28%) were used in poultry farms (Hossain et al, 2015).

The global overview of salmonellosis

Despite improvements in sanitation and hygiene NTS sickness continues to have a considerable negative impact on human health in both industrialized and developing nations. According to estimates, there are 93.8 million gastrointestinal illnesses caused by Salmonella species worldwide each year, resulting in 155,000 fatalities. *Salmonella enteritidis* was the most prevalent serotype globally (65% of the isolates), followed by *Salmonella typhimurium* (12%) and Newport (4), and according to data collected by Salmonella surveillance (a WHO supported food-borne disease monitoring network) between 2001 and 2005. *Salmonella Enteritidis* was the most prevalent isolate in Asia, Europe, and Latin America (38%, 87%, and 31%, respectively).

Salmonella Typhimurium was the most commonly reported Salmonella species in North America (29%) followed by *Salmonella Enteritidis* (21%) and other Salmonella species (21%), according to Majowicz (2010). *Salmonella Typhimurium* and *Salmonella Enteritidis* comprised 26% and 25%, respectively, of the isolates in Africa. Bloodstream infections with *Salmonella* species, particularly *Salmonella Enteritidis* and *Salmonella Typhimurium*, are more frequently linked to NTS in Sub-Saharan Africa than with Salmonella typhi or paratyphi, according to hospital-based studies.

Status of salmonellosis in Ethiopia

About 56 million chickens exist in Ethiopia, the majority of which (95%) are kept in low input, low output village chicken farming systems. Together with providing eggs and meat, chickens are a significant source of income for poor smallholder households. Ethiopia consumes 0.5 kg of eggs annually per capital, which is significantly less than the average sub-Saharan African country consumption of 2.3 kg.

Salmonella isolates in Ethiopia may have similar phenotypic and genotypic characteristics to isolates elsewhere in the world. NTS enteric infection in Ethiopia is a major health problem and is caused by similar serovars to those reported from elsewhere in Africa. Different studies indicated the widespread occurrence and distribution of Salmonella in Ethiopia and the resistance of the isolates to antimicrobial agents. In recent years the number of outbreaks of *Salmonella* in humans has increased considerably in the country (Table 1).

Table 1. Prevalence of *Salmonella* from different poultry samples in different sites of Ethiopia.

Sample type	Site	Prevalence
Chicken carcasses	Addis Abeba	14%
Egg contents and egg shells	Kombolcha	11.50%
Poultry	Jimma town	41.90%
Eggs	Addis Abeba	4.69%

Egg contents and egg shells	Alage, Ziway, and Shashemene	13.30%
Egg shell	Haramaya	0%
Cloacal swabs, fresh feces, litter, and poultry drinking water	Modgo, Centeral Ethiopia	19.40%
Cloacal swab, personnel hand swab, bedding	Northern Ethiopia	16.70%
Poultry	In and around Addis abeba	14.60%
Cloacal swab	Jimma town	2.41%
Chicken cloacal swab	Asosa	22.65%
Poultry	Kafa zone	9.27%
Feces, eggs, and meat	Central Ethiopia	16.15%
Poultry	Addis Ababa	15.50%

Public and veterinary health importance of chicken eggs

Chicken eggs are a good source of protein. All age groups consume them, either alone or combined with other foods like fried potatoes (chips). Despite their nutritional values they can as well cause health problems through consumption of contaminated eggs with pathogenic Salmonella spp. In developing countries cracked and fecal contaminated eggs are being sold at a low price and consumed which can act as risk factors to acquire Salmonella illness. Eggs are of economic importance based on poultry industry production which can rise farmer`s income worldwide. The intact egg has natural physical and chemical barriers which inhibit pathogens from entering into egg contents. Eggs contain antimicrobial components, however various bacteria, including Salmonella, can infect them, having adverse effects on both animal and human sectors. Salmonellosis, a zoonotic infection, is thought to be mostly transmitted between chickens and humans.

DISCUSSION

Public health significance of salmonellosis

One of the most commonly seen outbreaks of a food borne illness, salmonellosis is especially prevalent in developing countries such as India, Asia, and Africa. Due to its large morbidity and fatality rates, high endemicity, difficulties in adopting controls, and other factors, salmonellosis poses a concern to public health. There are approximately 93.8 million occurrences of gastroenteritis worldwide each year, making it the most prevalent type of NTS infection. Since outbreaks of salmonellosis have frequently been linked to poultry, including chicken products like eggs, the disease's major cause is usually recognized to be poultry.

Salmonella Enteritidis phagotype 4 was implicated in several outbreaks of food-borne illness in England during the 1980's, which were brought on by the consumption of foods containing poultry ingredients. This raised concerns about the presence of *Salmonella* species in foods derived from poultry, which led to an increase in awareness of the problem. Typhoid, paratyphoid, and NTS are the three different infections that can be caused by the infectivity of *Salmonella* in humans. Typhoid and para typhus fever are caused in humans by this illness. *Salmonella* Typhi and *Salmonella* Paratyphi is a pathogen that causes fever as well as symptoms in the form of leukopenia, septicemia, and immunological and neurological abnormalities. Complications from typhoid and paratyphoid may result in death. In the reverse, *Salmonella enterica* serovar Typhimurium, *Salmonella enterica* serovar enteritidis, *Salmonella enterica* serovar Newport, and *Salmonella enterica* serovar Heidelberg, cause gastroenteritis-limited, non-typhoidal infections of Salmonella, with clinical sign of nausea, vomiting, diarrhea, and bacteremia, but not lethal.

The chicken industry now places a high priority on preventing the spread of *Salmonella* spp. through food because of the potential effects on public health. Salmonella contamination in eggs and poultry is the main cause of salmonellosis, a common intestinal disease in humans. Salmonella is one of the diseases that have the most effect on population health, according to WHO, and is linked to outbreaks and sporadic occurrences of food borne illness. According to data from the Brazilian ministry of health, 43% of the 6,602 food borne disease outbreaks that were observed between 1999 and 2008 had Salmonella spp. as the etiological agent.

Economic significance of Salmonellosis

The modern world is interconnected and dependent on one another. As a result, localized outbreaks of food-borne illness are now a potential global concern. A contaminated food item can have an impact on people's health simultaneously in numerous nations due to globalization, trade, and distribution. One contaminated food ingredient may cause the destruction of literally tons of food, significant financial losses for the industry that produces it, trade restrictions, and negative consequences on the travel and tourism sector.

Salmonellosis is a significant socioeconomic issue in many countries, especially poor countries, where it is believed that this etiological agent is mostly to responsible for outbreaks of food-borne illness. The bacteria can have an immediate negative impact on producers or farmers, either directly or indirectly. These illnesses have a number of negative effects as well, such as productivity losses for poultry farms (such as production losses, treatment costs, market disruptions, and loss of income from activities involving poultry resources), infection of humans (morbidity, food safety and quality), prevention or control costs (public expenditure), and less than optimal use of production potential. In 2010 alone, the annual costs associated with salmonellosis were estimated at US$2.71 billion for 1.4 million cases. Similarly, in the US, the estimated costs of medical expenses, sick leaves and loss of productivity related to the high incidence of salmonellosis ranged from US$1.3 to US$4.0 billion a year.

CONCLUSION

The NTS especially serovars Typhimurium, Enteritidis, Heidelberg and Newport have been reported in many outbreaks of human salmonellosis around the globe and these outbreaks have been linked with consumption of *Salmonella* contaminated foods of animal origins such as poultry. NTS like many other enteropathogenic bacteria has evolved in utilizing a variety of virulence markers and other cellular machinery to colonize the host by attaching, invading and bypassing the host's gastrointestinal defense mechanisms. The spread of *Salmonella* is very widespread and persistent in the environment, it increases the difficulty in reducing the spread of *Salmonella* spp. it can even cause death in humans and animals. Apart from this, the emergence of antibiotic resistance in Salmonella is a major challenge in terms of effective treatment for the Salmonella infection. Limiting the use of antibiotics in feed is an effective measure to stop the spread of antibiotic resistance in poultry production.

RECCOMENDATION

Therefore, based on the above conclusions, the following recommendations are forwarded:

- It is recommended that Intervention tools that help prevent introduction of *Salmonella enteritidis* in to the poultry production facility include biosecurity, procurement of *Salmonella enteritidis* free replacement flocks, and keeping disease vectors out of the houses should be made
- Factors related to flock contamination are generally linked to biosecurity measures and the design of the premises where they are controlled, thus preventing the introduction, survival, and multiplication of germs or their vectors in poultry should be embraced
- The public should be made aware of risks associated with consumption of raw chicken eggs and raw eggs cracked during storage and transportation.
- Awareness creation for chicken farmers about improving farming practices and the risks of antimicrobial resistance demands special attention.

REFERENCES

1. Abda, S., Haile, T., and Abera, M., Isolation, identification antimicrobial susceptibility and associated risk factors of Salmonella in semi-intensive poultry farms of Kafa zone, Southwest Ethiopia. *Veterinary and Animal Science*, **2021**. 14:p. 1002-1006.
2. Abdi, R.D., et al, Determination of the sources and antimicrobial resistance patterns of *Salmonella* isolated from the poultry industry in Southern Ethiopia. *BMC Infectious Diseases*, **2017**.17: p. 1-12.
3. Abebe, E., Gugsa, G., and Ahmed, M., Review on major food borne zoonotic bacterial pathogens. *Journal of Tropical Medicine,* **2020**: p. 4674235.
4. Abera, B., Biadegelgen, F., and Bezabih, B., Prevalence of *Salmonella* typhi and intestinal parasites among food handlers in Bahir Dar Town, Northwest Ethiopia. *Ethiopian Journal of Health Development*, **2010**. 24(1).
5. Abunna, F., et al., Salmonella: Isolation and antimicrobial susceptibility tests on isolates collected from

poultry farms in and around Modjo, Central Oromia, and Ethiopia. *Journal of Animal and Poultry Sciences*, **2016**. 5(2):p. 21-35.

6. Addis, Z., et al., Prevalence and antimicrobial resistance of *Salmonella* isolated from lactating cows and in contact humans in dairy farms of Addis Ababa: A cross sectional study. *BMC Infectious Diseases*, **2011**. 11(1):p. 1-7.
7. Afema, J.A., Mather, A.E., and Sischo. Antimicrobial resistance profiles and diversity in *Salmonella* from humans and cattle, 2004–2011. *Zoonoses Public Health*, **2015**. 62(7):p. 506-517.
8. Aki.A. and Eticha.B. Isolation and antimicrobial resistance profile of salmonella isolated from chicken swab in asossa, bambasi and pawe poultry farms, benishangul Gumuz Regional State. *Researcher*, **2022**. 12(9): p. 57-74.
9. Alemneh, T., and Getabalew, M., Exotic chicken production performance, status and challenges in Ethiopia. *International Journal of Veterinary Science and Research*, **2019**.5(2): p. 39-45.
10. Ame, N.Y., Mohammed, L.A., and Ame, M.M., Review on public health importance of Salmonellosis of poultry in Ethiopia. *International Journal of Advanced Multidisciplinary*, **2022**. 9(6):p. 78-95.
11. Andres-Barranco, S., et al. Role of wild bird and rodents in the epidemiology of subclinical salmonellosis in finishing pigs. *Foodborne Pathogens and Disease*, **2014**. 11(9):p. 689-697.
12. Angelo, K.M., et al. Antimicrobial resistance among nontyphoidal *Salmonella* isolated from blood in the United States, 2003-2013. *Journal of Infectious Diseases*, **2016**. 214(10):p. 1565-1570.
13. Assefa, M., Teklu, A., and Negussie, H., et al., The prevalence and public health importance of Salmonella from chicken table eggs, Ethiopia. *American-Eurasian Journal of Agricultural and Environmental*, **2011**.11:p.512-518.
14. Barrow, P.A., The long view: *Salmonella* the last forty years. *Avian Pathology*, **2012**. 41(5):p. 413-420.
15. Barton, M.D., et al., Impact of antibiotic use in the swine industry. *Current Opinion in Microbiology*, **2014**. 19:p. 9-15.
16. Bayu, Z., et al., Identification and characterization of Salmonella species in whole egg purchased from local markets in Addis Ababa, Ethiopia. *Journal of Veterinary Medicine and Animal Health*, **2013**. 5(5):p. 133-137.
17. Beyene T, Tesega B., Rational veterinary drug use: Its significance in public health. *Journal of Veterinary Medicine and Animal Health*, **2014**. 6(12):p. 302-308.
18. Boere, A., et al., Business opportunities report poultry 3 in the series written for the “Ethiopian Netherlands business event 5-6 November. 19 pages. Rijswijk, The Netherlands. **2015**.
19. Boyen, F., et al., Non-typhoidal *Salmonella* infections in pigs: A closer look at epidemiology, pathogenesis and control. *Veterinary Microbiology*, **2008**.130(1-2):p. 1-9.
20. Braden, C.R., *Salmonella enterica* serotype Enteritidis and eggs: A national epidemic in the United States. *Clinical Infectious Diseases*, **2006**. 43(4):p.512-517.