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Review Article

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Review on public health importance of Salmonellosis of poultry in Ethiopia

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Abstract

Salmonellosis is an important zoonotic disease, which cause a serious illness in animals including birds and humans. The disease is caused by various serotypes of *Salmonella* which are aerobic and facultative anaerobic, gram-negative rods and motile with the exception of *S.pullorum and S.Gallinarum*. *Salmonella*, like most Enterobacteriaceae, are motile, no spore forming, reduce nitrates to nitrites, ferment glucose, and are oxidase negative. The genus of Salmonella consists of only two species, *Salmonella bongori and Salmonella enterica*, with the latter being divided into six subspecies; *S. enterica*sub spp. *enterica*, *S. enterica*subsp. *salamae*, *S. enteric* subsp. *arizonae*, *S. enterica*subsp. *Diarizonae*, *S. enterica*subsp. *Houtenae*, *and S. enterica*subsp. *Indicia*. It constitutes a major public health burden and represents a significant cost in many countries. The presence of any serotype of *Salmonella* in food renders that food unfit for human consumption. *Salmonella* are known for its wide range host. It can because variety of diseases in some hosts while in others, can be asymptomatic. Poultry and eggs are considered as major sources for these pathogenic microorganisms. The disease is transmitted from animal to animal, animal to human and human to human direct or indirect pathway. Among *Salmonella* spp. *Salmonella Enterica*is one of the *Salmonella* serotypes responsible for causing enteric disease in humans.

1. Introduction

Salmonellosis is one of the major food borne diseases in the world and it is estimated that 93.8 million cases of gastroenteritis due to *Salmonella* species occur globally each year, with 155,000 deaths. Ethiopia has about 56.87 million chickens comprising mainly indigenous chickens, with the majority (95%) kept in low-input low-out-put village chicken production systems (Duguma, 2009; CSA, 2015). 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 diseases remain one of the major public health and economic problems all over the world (Legnani *et al*., 2004).

The risk of food borne illness has increased markedly over the last 20 years, with nearly a quarter of the population at higher risk for illness (CDC, 2003; 2004). *Salmonella enteric* serovar Enteritidis is considered the major cause of human *Salmonellosis* outbreaks in the United States and Europe (Collard *et al*., 2008 and Gould *et al*.,2013), linked mainly to consumption of contaminated poultry products, including eggs (Braden 2006 and Much *et al*., 2009). Live poultry are considered the main reservoir for *Salmonellae*; the microorganism is present in the intestinal tract, skin, and feathers of living birds. Bacterial contamination of poultry carcasses and cuts are a result of improper hygienic measures, improper cooking, and abuse of temperature. The dissemination of infection throughout plants during processing occurs in the evisceration, cooling, packaging, and transport stages (Zhang *et al*., 2013).

Based on food standards, the presence of *Salmonellae* in foodstuff makes food unsafe for human consumption. The most serious form of *Salmonellosis* for humans is typhoid fever, which is still a major problem in developing countries, mainly due to the lack of sanitation and hygiene standards (Dougan *et al*., 2011). The disease is transmitted mainly via foodstuff and water contaminated with the pathogen, and it affects more than 90 million people worldwide yearly, with variable morbidity and mortality rates. In poultry, the severity of the infection depends on many factors, including the strain of *Salmonella*, the standard of hygiene, age of the bird, route of infection, and immune status of the bird (Chao *et al*., 2007).

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 (Wray and Davies, 2003).

Although most of the infections in humans cause mild gastroenteritis, life-threatening systemic infections are common especially among high risk categories (Raufu, 2013). Invasive non typhoidal *Salmonella* commonly cause infection among infants, children, elderly and immune-compromised individuals worldwide and especially in African countries, where these diseases are driven in part by co-infection with malaria or human immunodeficiency virus (HIV) (AoTT , 2015). Sources and modes of transmission of non typhoidal *Salmonella*are still poorly understood in Africa due to the lack of coordinated national epidemiological surveillance systems (Kagambèga, 2013).

Generally, *Salmonella* in food producing animals, including poultry, manifests as long periods of latent carriage with occasional faecal shedding, which is the leading source of contamination of feed, water and environment (Magwedere, 2015). Foods of animal origin, especially poultry and poultry products, are often involved in sporadic cases and outbreaks of human *Salmonellosis* (Sanchez-Vargas *et al.*, 2011). Prior to this Saif (2008) also quoted that poultry and poultry products are a common food borne illness vector and consistently among the leading animal sources of *Salmonella* that enter the human food supply. It also added that humans encountered this problem by consuming raw or undercooked food especially of poultry and egg products. The increased global population coupled with mass production of animal and human food and the rapid international trade in livestock and food products has worsened the problem (Molla, 2003).

Food animals harbor a wide range of *Salmonella* serotypes and act as source of contamination, which is of paramount epidemiological importance in non-typhoid human salmonellosis. Contamination of meat by *Salmonella* may occur at abattoirs from the excretion of carrier animals, contaminated abattoir equipment, floors and personnel and the pathogen can gain access to meat at any stage during slaughtering operations. Cross-contamination of carcasses and meat products could continue during subsequent handling, processing, preparation and distribution (Egualee*et al*., 2016).

Despite some attempts to study prevalence of *Salmonella* in Ethiopia, mainly in pig, cattle, poultry meat, minced beef and humans, (Ejeta*et al*., 2004). but the status of the problem in chicken table egg is poorly known. However, studiesmade elsewhere indicated that chicken eggs are important sources of *Salmonella* particularly among those raw consumers. One study in kombolcha town indicated that Out of the total 400 chicken table eggs examined for bacteriological status of *Salmonella*, an overall 11.5% prevalence of *Salmonella* was found (Ejeta*et al.*, 2004).Therefore, the objectives of this review are;

- ➢ To review the occurrence of *Salmonella* spp. in eggs and environment.
- ➢ To highlight the public health importance of S*almonella.*

2. Public health importance of salmonellosis of poultry

2.1. Characteristics, Taxonomy and Nomenclature of salmonella

Salmonella was initially discovered and isolated by Theobald Smith in 1855 from pigs infected with Hog cholera or Classical Swine Fever (CSF). Dr. Daniel Elmer Salmon, an American pathologist with Smith, identified the bacterial strain. The nomenclature of Salmonella is still very controversial and growing. The Centers for Control and Prevention of Diseases (CDC) currently uses the World Health Organization (WHO) recommended name scheme of Salmonella (Engs*et al*., 2015; Popoff*et al*., 2001). The Salmonella genus belongs to the family *Enterobacteriaceae*, with two species, S. enteric and s.bongori (Shinohara et al., 2008; Annemarie *et al*., 2018).

Salmonella enterica, being divided into six subspecies; *S. enterica*sub spp. *enterica*, *S. enterica*subsp. *salamae*, *S. enteric* subsp. *arizonae*, *S entericasubsp.Diarizonae*, *S. enterica*subsp. *Houtenaeand S.enterica*subsp. *Indicia*. Enterica sub spp, salmonella *subsp. Enterica* (I) occurs primarily in mammals. In humans and warm blood blooded animals, about 99 per cent of salmonella infections. In comparison, Salmonella *Bongori* is predominantly found in cold blooded and environmentally friendly animals and seldom infects humans (Engs *et al*., 2015; Brenner *et al*., 20006). Salmonella *spp*. is a Gram-negative rod-shaped bacteria which is one of the most common infectious agents in the tropics, especially in areas with poor hygiene (Bell *et al.*, 2016).

The source of infection with Salmonella *spp*. Comes from human or animal feces or urine which contaminates drinking water and food so that it becomes a source of infection, besides fish, flies and dust can also act as intermediaries for salmonellosis (Barbour *et al*., 2015; Pui *et al*., 2011; Loharikar *et al*., 2013). Salmonella spp classification Serotype dependent on 3 major antigens, i.e.,*somatic* (O), capsule (K), and *flagellum* (H). *Somatic antigen* (O) is positioned outside the membrane of the bacterial cell and has stable heat to form the *lipopolysaccharide (LPS) oligosaccharide* portion of the bacterial cell... A unique salmonella serotype can express more than one O antigen. The thermally-labile H antigen is used to activate the immune response of the host and is found mainly in bacterial flagella’s.

Much of the spp. Salmonella. It has two different genes that flagella encode. These bacteria can be diphasic (phase I and II), so they can release one protein at a time only. Immunologically responsible Phase I H antigen can be expressed in many serotypes, whereas phase II antigen does not have the same characteristics and is present in several other serotypes (Leekm *et al*., 2015; MCQuiston *et al*., 2008).

The *K* antigen surface is rarely found between most serotypes of Salmonella and heat sensitive polysaccharides mainly located on the surface of the bacterial capsule. Only *Paratyphi* C, *Dublin* and Typhi serotypes were found for the *K* antigen subtype virulence (VI). In literature, the term serovar, synonymous with serotype, is widely used. In general, the subspecies in the specific classification Salmonella serotype are omitted. Reading literature like S, for example Typhi*enterica* subspecies *Typhi* is generally reduced to Salmonella serotype *Typhi* (Poppof *et al.,* 2001; Rahmaniar*et al*., 2020).there were currently 2500 serotypes, each of which has a somatic (O) antigen combination with flagellular antigens H1 and H2... More than 50 percent of these serotypes are S. *enterica*. It accounts for the majority of human Salmonella infections (Jajare,2019; Guibourdenche*et al* 2010).The most important pathogenic members of avian salmonellosis include Salmonella *enterica subsp. entericaserovarGallinarum* and Salmonella *enteric*a Subsp. *Entericapullorum* (Nazir *et al.*, 2012). There are host specific and represent a major concern for the poultry industry causing fowl typhoid and pull rum disease (Rosu *et al.*, 2007).

In humans, Salmonella, which is infectivity, has three distinct infections: *typhoid*, *paratyphoid* and *non-typhoid* Salmonella (NTS). Salmonella is the cause of typhoid and paratyphus fever. S. *Entericaserovar Paratyphi*, a fever characteristic and complications, including septicemia, immunological symptoms, leukopenia, and neurology. *Typhoid* and *paratyphoid* complications may cause death (Chong *et al.*, 2017). In the reverse, *S. Murinumtyphimurum*, S. *enteritidis*, salmonella *enticaserovar Newport* (Newport S.), and salmonella *enticaserovar* Heidelberg (H.), cause gastroenteritis-limited, non-typhoidal infections of Salmonella, such as nausea, vomiting, diarrhea, and bacteremia. But not lethal. There can be no distinctive clinical signs of typhoid fever and paratyphoid fever, which renders 'enteric fever' a mixture of both. Also S. *Typhus* and S.*Paratyphoid* called typhoid Salmonella (Connor *et al., 2005*, Engs *et al.*, 2015). Two forms of Salmonella typhoid are stored in humans. Bacteria are spread by food or water intake. Enteric fever is typically characterised by a period of incubation of a week or more accompanied by symptoms such as headache, stomach pain and oral (or constipation) diarrhoea (Engs *et al*., 2015, Bhan *et al*., 2005). Aside from fever, myalgia, bradycardia, hepatomegaly, splenomegaly and chest and stomach rashes can be encountered in infected men (Engs *et al*., 2015; Kufandik *et al*., 2009).

Salmonella strains other than *S. typhi* and *S. paratyphi* are often referred to as *non-typhoid* Salmonella (NTS) and the main reservoir is animals. *NTS* infection is characterized by gastroenteritis in which there is an inflammatory condition in the digestive tract accompanied by symptoms such as bloodless diarrhea, vomiting, nausea, headache, stomach cramps, and myalgia. Symptoms such as hepatomegaly and splenomegaly are rare in patients infected with NTS (Engs *et al*., 2015; Hohman*et al.*, 2001).

Gastrointestinal complications from NTS infection such as cholecystitis, pancreatitis, and appendicitis, whereas terminal ideal perforation was not associated with NTS infection (Hohman *et al*.,2001). Chronic carriers are characterized as bacteria that are carried through the heat for more than one year following the acute Salmonella infection. Since people are the Salmonella typhoid source, S.paratyphoid and typhoid. Paratyphoid can be transmitted to human beings through common routes of transmission, such as water consumption or food contaminated by carrier faeces (Bhan *et al*., 2005). In addition, people as NTS carriers are rare at 0.1% concentrations, since animals are the main stockpile of NTS

(Hohman *et al.,* 2001). NTS is a disease that is prevalent in the entire world and is self-restricted diseases. Salmonella infection is the most common cause of this disease. Enteric fever, by comparison, is highly morbid and mortal and is widespread particularly in under developed countries due to salmonella typhoid (AFSSA, 2009).

Salmonella spp. is bacteria that are widespread in the environment that can be isolated from the intestines of most mammals, reptiles and birds. More than 2,500 serovars of Salmonella have been identified. Further studies have shown that Salmonella is capable of surviving for approximately 87 days in tap water, 115 days in pond water, 120 days in pasture soil and 280 days in garden soil(Sencer and Guan,2004) The key factors identified in Salmonella survival time in an external environment were temperature, frost, moisture content, humidity, sunlight, (Sencer and Guan,2004).

2.2 Salmonellosis

Salmonellosis is one of Salmonella spp's most common enteric pathogenic diseases. It has a high degree of morbidity and preventive issues (Anderson *et al.*, 2016; Scallan *et al*., 2011). Poultry is an important reservoir of bacterial agents. Infected poultry can be a source of disease transmission. Pathogenic microorganisms can cause infectious disease, which is the main disease and the highest cause of death in animals and humans (Suardana *et al.,* 2014). The increasing incidence of infectious diseases causes the use of antibiotics to be the most dominant in health services (Noor and poeloeng, 2014).

2.2.1. Epidemiology of Salmonella

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. Approximately 2500 different *Salmonella* serovars have been described, and the number increases annually as new serovars are recognized (Wray and Davies, 2003).

The epidemiology of *Salmonellosis* 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 (Rounds *et al*.,2010).

According to the WHO Global Salm-Surv, during2000-2002, *S. enteritidis* was by far the most common serotype reported from humans globally. In 2002, itaccounted for 65% of all isolates, followed by *S. typhimurium* at (12%) and *S.* Newport at (4%).Among non- human isolates, S. typhimurium was the most commonly reported serotype in all the three years, accounting for (17%) of isolates in 2002followed by *S.* Heidelberg (11%) and *S*. Enteritidis (9%). *Salmonella* Enteritidis, *S.* Typhimurium and *S.*Typhi were ranked among the fifteen most common human serotypes in all regions of the world throughout the three year study period. *Salmonella* Agona, *S.*Infantis, *S.* Montevideo, *S.* Saintpaul, *S.* Hadar, *S.*Mbandaka, *S.* Newport, *S.* Thompson, *S*. Heidelberg and *S*. Virchow were also widespread. In Africa in2002, *S*. Enteritidis and *S*. Typhimurium were each reported from approximately one fourth of isolatesfrom humans (Galanis *et al*., 2006 and Swaminathan *et al*., 2006).

2.2.2. Pathogenesis

Transmission of *Salmonellae* is usually by the fecaloral route but infection via mucous membranes of the conjunctivae or upper respiratory tract is suspected. *Salmonellae* are often pathogenic to humans or animals when acquired by oral route. *Salmonellae* need to colonize the distal small intestine and the colon is a necessary first step in the pathogenesis of enteric *Salmonellosis*. Indigenous fusiform bacteria that lie in the mucous layer infesting the epithelium of the large intestine normally inhibit growth of *Salmonella* by producing volatile organic acids. Thenormal flora also blocks access to attachment sites needed by the pathogens. Factors, which disrupt the normal colonic flora, such as antibiotic therapy, diet, and water deprivation, greatly increase the host's susceptibility to enteric and septicemic Salmonellosis. Reduced peristalsis also enhances colonization by *Salmonella* because it allows temporary overgrowth to occur, especially in the small intestine. Peristalsis is stimulated by an active indigenous microflora, suppression of which increases the host's susceptibility to colonization (Venter *et al.,* 1994;Gillepsie and Timoney, 1981).

Following an adhesion-dependent attachment of *Salmonellae* to luminal epithelial cells, the invasive pathogen is internalized within an epithelial cell by a receptor-mediated endocytotic process. Cytotoxin localized in the bacterial cell wall suggestively may facilitate *Salmonella* entry into the epithelial layer. Cytoplasmic translocation of the infected endosome to the basal epithelial membrane culminates in the release of *Salmonellae* in the lamina propria. During this invasive process, *Salmonella* secretes a heat-labile enterotoxin that precipitates a net efflux of water and electrolytes into the intestinal lumen. However, some strains of S. Typhimurium are known to produce enterotoxin-like substances. Inflammatory enteritis quickly develops and is characterized by extensive neutrophil invasion of villous cores withacute ileitis and colitis. Neutrophils are also shed inthe stool, and their presence has diagnostic value (Venter *et* al., 1994; Gillepsie and Timoney, 1981).

The pathogenesis of the septicemic phase of Salmonellosis appears to be related to the effects of endotoxin released from bacterial cells (Wray andDavies, 2000; Gillepsie and Timoney, 1981). In *Salmonella,* endotoxic activity resides in the lipopolysaccharide of the cell wall. The lipopolysaccharide is composed of an O– specific chain, a core oligosaccharide common to all *Salmonella*, and a lipid A component. The latter is thepart of the lipopolysaccharide molecule that contains endotoxin activity. The effect of endotoxin on the hostincludes fever, mucosal hemorrhages, leucopenia followed by leukocytosis, thrombocytopenia, and depletion of liver glycogen with prolongedhypoglycemia and shock. The shock effect may be severe and irreversible and may lead to death(Gillepsie and Timoney, 1981).

2.2.3. Salmonella Infections in poultry

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 inits 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. abortusequi*. Other clinically apparent or in apparent infections are caused by serotypes with multiple hosts (CDC, 2005).

Two serotypes, *S. Gullorum* and *S. Pallinarum*, are adapted to domestic fowl. They are not very pathogenic for man, although cases of *Salmonellosis* caused by these serotypes have been described in children. Many other serotypes are frequently isolated from domestic poultry; for that reason, these animals are considered one of the principal reservoirs of *Salmonellae*. Pullorum disease, caused by serotype *S.pullorum*, and fowl typhoid, caused by *S. gallinarum*, produce serious economic losses on poultry farms ifnot adequately controlled. Both diseases are distributed worldwide and give rise to outbreaks withhigh morbidity and mortality. Pullorum disease appears during the first 2 weeks of life and causes high mortality. The agent is transmitted vertically as well as horizontally. Carrier birds lay infected eggs that contaminate incubators and hatcheries. The infection in adult birds is generally asymptomatic, but during the first few weeks of life, its clinical picture is similar to pullorum disease (loss of appetite, nervous symptoms, and blockage of the cloaca with diarrheal fecal matter). The highest mortality occurs during thefirst two weeks of life. Most losses occur between sixand ten days after hatching (CDC, 2006).

2.2.4. Salmonellosis in Humans

Salmonella infections in humans can range from a self-limited gastroenteritis usually associated with non-typhoidal *Salmonella*(NTS) to typhoidal fever with complications such as a fatal intestinal perforation (OIÉ, 2019). Non-typhoidal *Salmonella* is one of the principal causes of food poisoning worldwide with an estimated annual incidence of 1.3billion cases and 3 million deaths each year (Torpdahl *et al*., 2007). Outbreaks of *Salmonellosis* have been reported for decades, but within the past 25years the disease has increased in incidence in many continents. The disease appears to be most prevalent in areas of intensive animal husbandry (OIÉ, 2019).The incubation period in people is variable but is usually between 12 and 36 hours. The typical presenting symptom is diarrhea but this may be accompanied by nausea and abdominal pain, although vomiting is not usual. There may also be a headache and fever. While the infection is normally self-limiting and does not require antibiotic treatment, occasionally, with more invasive *Salmonella* such as *S*. Virchow,bacteremia can occur. The infection is rarely fatal in people (Gracey *et al.*, 1999).

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* can replicate both inside the vacuoles of host cells and in the external environment. *Salmonella* are the second most common pathogens isolated from humans with gastroenteric disease in developed countries (Buncic, 2006). *Salmonella typhimurium* and *S.enteritidis* occur inthe gastro intestinal tract of animals, including livestock. The disease is self-limiting, but can be severe in young, elderly or otherwise IC(immune-compromised) people. *Salmonella* invade epithelial cells in the ileum and proliferate in the lamina propria and profuse, watery diarrhoea results. Some isolates produce a heat-labile enterotoxin, which initiates diarrhoea. Sequelae include post-enteritis reactive arthritis and reiter's syndrome and systemic infection can result. Individuals can develop carrier status of up to 6 months in duration. The infectious dose varies, from only a few CFU to >105 CFU, so growth of the pathogen in foods has not been a factor in all cases of foodborne Salmonellosis, but appears to have been in some. Foods known to have been vehicles of *Salmonellosis* include poultry, eggs, and meat, milk, chocolate, coconut and frog legs. However, any faecally contaminated food can be implicated (Buncic, 2006).

Salmonella typhi and *S. enteric* subsp. *Paratyphi* cause the systemic diseases typhoid fever and paratyphoid fever, respectively. These pathogens occur in human faeces, and are spread via human faeces to the environment and to foods. Person-to-person transmission is common. The disease symptoms of typhoid and paratyphoid fevers are dissimilar to those of enteric Salmonellosis. *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 ileumcan occur if organisms multiply in the bile of the gallbladder and cause re-infection. Any food could be a vehicle of infection if contaminated with human faeces. 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 faeces (Buncic, 2006).

2.2.5. Control and Prevention of Salmonellosis

The preventive methods for reducing the risk of Salmonella contamination of shell eggs and human salmonellosis outbreaks due to their consumption can be either applied as pre harvest or as postharvest procedures .The environment of the laying hen house can act as reservoir for Salmonella, along with the feed that can be already contaminated as it arrives in the farm (Umali *et al.*, 2012). Due to these various sources of infection for the laying hens, preventive methods are already applied or available at the farm level: flock testing, sanitation and biosecurity; vaccination; passive immunization (Chalghoumi *et al*., 2009); the use of natural antimicrobial products such as bacteriophages (Toro *et al*., 2005) protein and fiber sources (Kassaify and Mine, 2005) competitive exclusion flora, probiotics, prebiotics, and organic acids (Chalghoumi *et al*., 2009) essential oils (Johny *et al*., 2008) and bacteriocins (Dias Paiva *et al*., 2011). For postharvest control of Salmonella in shell eggs, the first approach is to maintain an adequate temperature during storage (Gantois *et al*., 2009).

However, different surface decontamination methods are already applied in the U.S.A. and new ones make the subject of continuous research: egg washing (Caudill *et al*., 2010) ultrasounds (Cabeza *et al*., 2011) microwaves (Lakins *et al*., 2008) irradiation (Cabo Verde *et al*., 2004).gas plasma (Ragni *et al.*, 2010) ultraviolet light; and pulsed light. Among all these, the ones authorized in the U.S.A. are the shell washing and irradiation. Salmonellosis is a major concern in food safety. European Union has enacted regulations since January 2006 covering control measures implemented throughout the poultry production chain, including production levels, biosecurity measures, and prohibiting the use of antibiotics as growth promoters (Vandeplas *et al.*, 2010).

Salmonella prevention and control can be achieved by adopting the principles of HACCP (Hazard Analysis Critical Control Point) (OIE, 2019).Hygiene and biosecurity should be part of the overall management of the farm. These steps are very important in infection control. Incoming poultry must have a high health status and must be purchased from reliable suppliers that have quality-assured breeding and hatchery facilities. Furthermore, Salmonella can be transmitted in chicken farms through vehicles, workers, clothing, footwear, equipment, water, food, garbage, insects, rodents, wild birds, pets, equipment, and many other factors. Reducing *Salmonella* prevalence requires a multi hurdle approach at all stages of breeding, hatching, grow-out, transportation and processing.

Attenuated DNA recombinant live *Salmonella* vaccines, combined with comprehensive control strategy in animals, feed and animal food stuffs will help to reduce Salmonellosis. Additional measures to control secondary contamination could be prevention of contamination by cleaning and disinfection, hygiene of personnel and proper processing (Sinell, 1995).

Growth of micro-organisms in meat and poultry products can be controlled by maintaining a cold chain at 10oC, especially for *Salmonella* during transport and storage (Coleman *et al.,* 2003). Vaccination does not offer complete protection of the birds against infection. An effective way to control *Salmonella* in eggs is by preventing the vertical spread of *S. enteritidis* between different generations of birds (CDC, 2005).

2.2.6. Salmonellosis and Public Health

Growth in international trade and current facilities for traveling increased not only the dissemination of pathogenic agents and contaminants in foodstuffs, but also our vulnerability. Nowadays, the world is interrelated and interdependent. Thus, local foodborne disease outbreaks have become a potential threat for the whole world. Globalization, commercialization and distribution make it possible for a contaminated foodstuff to affect the health of people in several countries at the same time. Therefore, there is an ever growing perception of the need and importance for surveillance systems and adoption of measures to ensure food safety, such as the identification of the foods involved in food borne disease outbreaks (Tauxe *et al*., 2010).

Salmonella is an intestinal bacterium responsible for severe foodborne intoxications. Salmonellosis is an important socioeconomic problem in several countries, mainly in developing countries, where this etiological agent is reported as the main responsible for foodborne disease outbreaks. It is one of the most problematic zoonosis in terms of public health all over the world because of the high endemicity, but mainly because of the difficulty in controlling it and the significant morbidity and mortality rates (Tessari *et al*., 2003).

The CDC regularly reports Salmonella outbreaks that are associated with poultry and poultry products (CDC, 2005).and these food products are generally recognized as a primary source of salmonellosis. Poultry and eggs are considered one of the most important reservoirs from which Salmonella is passed through the food chain and ultimately transmitted to humans. With increasing consumption of poultry and poultry products, the number of salmonellosis associated with poultry continues to be a public health issue in the US. Since Salmonella is a major causative agent for poultry-associated foodborne illnesses, improving safety of poultry products by early detection of foodborne pathogens would be considered an important component for limiting exposure to Salmonella contamination. This monitoring of poultry and other related products for Salmonella contamination could be made significantly more effective by employing rapid and sensitive detection systems. Transmission of Salmonella to humans typically occurs when ingesting foods that are directly contaminated by animal feces or cross contaminated by other sources (Modaressi *et al.*, 2010).

Historically, *Salmonella Typhimurium* was the most common agent of the foodborne disease in humans, although in the past decades *Salmonella Enteritidis* has been most frequently involved in salmonellosis outbreaks. There is a growing concern about human infections caused by other serovars, such as Infants, Algona, Hagar, Heidelberg and Virchow (Freitas-Neto *et al*., 2011). Concerns about the presence of *Salmonella spp*. in foodstuffs of poultry origin increased in the 1980s, when *Salmonella Enteritidis* phenotype 4 was responsible for several outbreaks of foodborne disease in England, caused by the ingestion of foods containing poultry ingredients. The vertical transmission of *Salmonella Enteritidis* in commercial poultry was responsible for the increased number of cases of human infection in Europe, North America and other parts of the world. These species replaced *Salmonella typhimurium*, which was the most common agent of human foodborne infection until the 1980s (Olsen *et al.*, 2003).

In the European Union, *Salmonella Enteritidis*, *Salmonella Typhimurium*, *Salmonella Infants*, *Salmonella Hadar* and *Salmonella Virchow* are considered by the European Food Safety Authority the most important serovars in terms of public health (Van-Immerseel *et al.*, 2007). In 2005, in the US, the serovars that were most frequently isolated from human sources were *Salmonella Typhimurium*, *Salmonella Enteritidis*, *Salmonella Newport*, *Salmonella Heidelberg* and *Salmonella Javiana* (CDC, 2007)

Besides the importance of preventive measures against the risk of Salmonella infection in humans, control of salmonellosis has a positive economic impact in countries where outbreaks occur. Estimated costs of medical expenses, sick leaves and loss of productivity related to the high incidence of salmonellosis in the US range from US$1.3 to US$4.0 billion a year (Toro *et al.*, 2005).

Depending on the host species and age, and on the pathogenicity of the microorganism and its adaptation to the host, Salmonella may cause severe disease, or go unnoticed and remain in the host for months or years. In this case, the host will be a reservoir of the bacteria for susceptible animals. The most common symptoms include diarrhea, abdominal pain, vomit and nausea, and may occur together with prostration, muscle pain, drowsiness and fever. Although symptoms generally disappear after 5 days, the microorganisms may be excreted in the feces for many weeks. Children, mainly those younger than 1 year of age, elderly and immune-compromised patients are much more susceptible to the disease, and may present more severe infections, such as sepsis, which may lead to death (Pinto *et al.*, 2004).Since 1980, human outbreaks caused by *Salmonella Enteritidis*, showed common sources in the US, Great Britain and other European countries (CDC *et al*., 2005).

Epidemiological surveys from the CDC identified the consumption of eggs or egg-based foods as responsible for most of the outbreaks involving specific phagocyte (PT) of *Salmonella Enteritidis*; *PT-4* in European countries, and *PT-8* and *PT-13a* in the US. (CDC, 2005). The predominant serotypes involved in foodborne diseases changed, in the past decades, from *Salmonella Agona*, *Salmonella Hadar and Salmonella Typhimurium* to *Salmonella Enteritidis*, which is the predominant cause of salmonellosis in several countries (Suresh *et al*., 2006).

The typification of serovars is important to track the source of infection. For example, *Salmonella Agona* affected humans in the US, in European countries and in Brazil. The intensive breeding system adopted by the poultry industry favors the introduction, establishment, permanence and dissemination of these bacteria.(Suresh et al.,2006).Therefore, the stage when animals are raised is very important in the dissemination of *Salmonella spp*. among the birds, and consequently, in giving rise to contaminated food products. Salmonella may affect all segments of poultry production, such as breeder facilities, incubators, commercial raising operations, feed factories, slaughterhouses, transportation systems and commercialization facilities (CDC, 2005).

3. Conclusion and Recommendations

Salmonella *spp*. has always been a major public health problem that occurs worldwide. The spread of Salmonella is very widespread and persistent in the environment, it increases the difficulty in reducing the spread of Salmonella spp. Salmonella spp. it can even cause death in humans and animals... It's one of the most prevalent foodborne pathogen, its main reservoir being considered the shell egg. As the concerns related to the increasing human salmonellosis cases grow, the need for an application of preventive methods either at the farm level or during the processing steps is crucial for a better control of the foodborne outbreaks due to the consumption of this specific food product. The use of different preventive methods has the effect of reducing the likelihood that eggs become contaminated with *Salmonella spp*., especially with *S. enteritidis*. Reducing *Salmonella* prevalence requires a multi-hurdle approach at all stages of breeding, hatching, grow-out, transportation and processing. Therefore additional measures to control secondary contamination could be prevention of contaminationby cleaning and disinfection, hygiene of personnel andproper processing. On the farm level, the different preharvest methods may reduce the risk of egg contamination by interfering in the infection process and reducing the likelihood of this foodborne pathogen penetration in the forming egg. Further on, postharvest methods may reduce the risk of human salmonellosis, by respecting the refrigeration step and by different procedures, either chemical or physical. These latter reduce the existing bacterial counts, especially on the egg shell and ensure the microbiological quality of the shell eggs marketed in different parts of the world. Based on the above conclusion the following recommendations are forwarded:

- Eggs should be properly handled, refrigerated, and cooked.
- All eggs for sale must be candled to remove cracked eggs.
- Cracked eggs must be disposed of or only sold to businesses to be pasteurized.
- Nests should be kept as clean as possible by removing faeces and broken eggs out of nests and cleaning nest pads.
- Eggs should be cool immediately after collection at 15 ºC and be capable of maintaining this temperature, eating raw or undercooked eggs should be avoided.
- Premises and equipment for handling and storage of eggs must be maintained in a sanitized state fit for the production of food for human consumption.
- Hands, cooking utensils, and food-preparation surfaces should be washed with hot water and soap.
- You should be avoiding contaminating the egg contents with the outside of the shell when cracking.

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