Review Article

The Role of Poultry in Food Borne Salmonellosis and its Public Health Importance

Jinu Manoj[1*], **Manoj Kumar Singh**[2], **Yesh Pal Singh**[3]

[1]Veterinary Public Health and Epidemiology; [2]Livestock Production and Management; [3]College of Veterinary & Animal Sciences, SVPUA&T, Meerut, 250110, India.

Abstract | *Salmonella* organisms are most frequently isolated bacterial agents of food borne outbreaks. Due to its economic importance and risks to human health, salmonellosis poses significant role in public health. Poultry serves as reservoir of *Salmonella* and poultry meat and eggs have been implicated in food associated outbreaks of salmonellosis. The presence of *Salmonella* in poultry makes the food chain unsafe from farm to the table. In this review, we explore various public health aspects of food borne salmonellosis originated from poultry. In India, poultry industry is one of the fastest growing segments and the factors linked to salmonellosis in poultry industry are reviewed. The sources and modes of transmission of this organism and the disease symptoms are briefly explained. Various reports of salmonellosis in poultry, with special emphasis on Indian conditions are also discussed. The emergence of multidrug resistant *Salmonella* is considered as a major global threat to public health, therefore, the antibiotic resistance in *Salmonella* serovars associated with poultry is also presented.

Keywords | Antibiotic, Poultry, Public health, Resistance, Salmonellosis, Significance

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***Correspondence** | Jinu Manoj, College of Veterinary & Animal Sciences, SVPUA&T, Meerut, India; **Email:** drjinumanoj@gmail.com
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INTRODUCTION

Food borne diseases are a serious concern as public health issue in the food industry. *Salmonella* organisms are most frequently isolated bacterial agents of food borne disease outbreaks and are of significant public health concern. Due to its significant morbidity and mortality rates salmonellosis causes risks to human health and economic loss (Vo et al., 2014). WHO's Food borne Disease Burden Epidemiology Reference Group (FERG) shows that from 2010, there were an estimated 582 million cases of 22 different food borne enteric diseases, among them *Salmonella* were the main enteric disease agent responsible for most deaths (WHO, 2015).

Salmonella organisms are Gram negative, facultative anaerobic, non-spore forming, rod shaped bacilli belonging to the family *Enterobacteriaceae*. The genus *Salmonella* was named after Daniel E. Salmon who first reported the isolation of *Salmonella* from a pig in 1885 and named the organism as *Bacterium choleraesuis* (Molbak et al., 2006). *Salmonella* genus consists of two species, *Salmonella enterica* and *Salmonella bongori*. *S. enterica* is divided into six subspecies: *S. enterica* subsp. *enterica, S. enterica* subsp. *salamae, S. enterica* subsp. *arizonae, S. enterica* subsp. *diarizonae, S. enterica* subsp. *houtenae* and *S. enterica* subsp. *indica* (Popoff et al., 2004). The antigenic formulae of *Salmonella* serovars are listed in a document called White-Kauffmann-Le minor scheme (Grimont and Weill, 2007), based on which *Salmonella* strains are serologically classified. Till date 2610 serotypes have been recognized by the WHO Collaborating Center for Reference and Research on *Salmonella* (WHO-Salm), Institut Pasteur, Paris, France (Guibourdenche et al., 2010). The important zoonotic salmonellae almost exclusively belong to subspecies *enterica*. Serotypes such as *S. typhimurium* and *S. enteritidis* can infect a wide range of hosts and represent most frequent causes of foodborne illnesses (Park et al., 2014), whereas *S. gallinarum* and *S. pullorum* are avian-specific strains (Foley et al., 2011).

POULTRY AS A SOURCE OF SALMONELLOSIS

Among livestock production systems, *Salmonella* is more frequently isolated from poultry (chicken, turkey, duck, geese and pheasants) than from other animals (OIE, 2008). In recent years public health problems associated with salmonellosis were of poultry origin (CDC, 2013). Poultry and eggs are considered as most important reservoirs from which *Salmonella* is passed through the food chain and ultimately transmitted to humans (Howard et al., 2012). The levels of this pathogen in poultry can vary depending on country, production system and the specific control measures in place. Poultry can carry some *Salmonella* serovars without any outwards signs or symptoms of disease. *Salmonella* can contaminate eggs on the shell or internally, but the egg shells are much more frequently contaminated than the white/yolk. Furthermore, egg surface contamination is associated with many different serotypes, while infection of the white/yolk is primarily associated with *S. enteritidis* (Herikstad et al., 2002). Contaminated poultry and poultry-derived products, including meat and eggs are a major source of food borne salmonellosis (Barrow et al., 2012; Barua et al., 2013). *Salmonella* is able to remain viable in frozen products as well as foods stored at high temperatures for long periods, due to their marked *ability* to persist in a wide range of varying environmental conditions (Balamurugan, 2010).

Salmonella can enter the food chain at any point. Contamination can occur at several stages in the slaughter process of poultry, like faeces during evisceration, surfaces on the production line or cross contamination from contaminated products. Particular contamination hot spots in the poultry slaughter process include defeathering, evisceration and cutting, while chilling in a water bath enhances cross-contamination (Northcutt et al., 2003). The principal site of multiplication of these bacteria is the digestive tract, particularly the caecum (Beal et al., 2006), which may result in widespread contamination of the environment due to bacterial excretion through faeces (Kabir, 2010).

Salmonella can be introduced to a flock via environmental sources such as feed, water, soil, bedding, litter material, faecal matter, rodents or contact with other poultry. This pathogen can survive in the farm environment for long periods of time (Petkar et al., 2011). Horizontal transmission of *Salmonella* via contaminated water, feed, faecal material, bedding material and vertical transmission via eggs may occur in birds (Jones, 2011; Ricke et al., 2013). As *Salmonella* colonizes the gastrointestinal tract, the organisms are excreted in feces from which they may be transmitted by insects and other animals to a large number of places and are generally found in contaminated water with faeces. Humans and animals that consume polluted water may shed the bacteria through fecal matter continuing the cycle of contamination. All the fractions of poultry production can be affected by *Salmonella* organisms, like hatchery, incubators, breeding facilities, commercial raising operations of layers and broilers, feed preparation units and factories, transportation systems, commercialization facilities and slaughter houses (Rodriguez et al., 2006; Hoelzer et al., 2011).

PUBLIC HEALTH SIGNIFICANCE OF SALMONELLOSIS

With the increase in poultry meat and egg consumption, the dynamics of animal production and consumer exposure have changed leading to new challenges in limiting poultry borne zoonosis like salmonellosis. This has significant implication in India where poultry industry is the fastest growing segments with a growth rate of 8-10%. Globalization, commercialization and distribution make it possible for a contaminated foodstuff to affect the health of people in several countries at the same time. The identification of only one contaminated food ingredient may lead to the discard of entire lot, causing economic losses to the production sector and restrictions for international trading. The loss in animal production and public health issues associated with salmonellosis has a substantial impact on the economy of several countries (Hoelzer et al., 2011; Mather et al., 2013).

Salmonella is mostly transmitted to humans, through contaminated food and water. In hospitals, person to person transmission may also happen. Among veterinarians and farm workers, transmission by contact with infected animals is possible. Cross contamination of poultry can occur in slaughter houses as well as during preparation of poultry products (Olsen et al., 2003). Most of the *Salmonella* serotypes are pathogenic to humans and the common symptoms of salmonellosis in human are abdominal pain, diarrhea, nausea, vomiting, muscle pain, prostration, drowsiness and fever. Symptoms observed may be different due to variation in the dose of inoculation, mechanisms of pathogenicity, virulence factors, age and immune response of the host (Andino and Hanning, 2015). *Salmonella* can also leads to severe condition like sepsis and death especially in infants and immunocompromised adults (Tessari et al., 2012). Other than gastroenteritis, *Salmonella* may also cause extra intestinal infection like meningitis, osteomyelitis, arthritis, pneumonia, colecystitis, peritonitis, pyelonephritis, endocarditis, pericarditis, vasculitis and chronic condition like aseptic arthritis and Reiter's syndrome (Andino and Hanning, 2015).

Several cases of food borne salmonellosis originated from poultry products has been reported globally (Calvert et al., 2007; Zielicka-Hardy et al., 2012; Jakociune et al., 2014). Isolation of *Salmonella* from chicken also reported (Dallal et al., 2014). The predominant serovars of *Salmonella*, having public health importance are mainly *S. enteritidis* and *S. typhimurium* (Jinu et al., 2014). Changes in the environment and poultry raising practices along with increased international trading of poultry and its products made changes in predominance of *Salmonella* serotypes. Recent concern in public health point of view is antibiotic resistant serotypes. Antibiotics as growth promoters are of utmost concern because its usage in subtherapeutic levels, stimulate survival of resistant bacteria in the ecosystem (Al-Ferdous et al., 2013). The WHO observed an alarming rate increment of resistant *Salmonella* strains due to the abusive use of antibiotics in intensive animal raising (WHO, 2014). According to CDC's National Antimicrobial Resistance Monitoring System (NARMS), the serovars with greater resistance to antimicrobials are *S. typhimurium*, *S. enteritidis*, *S. newport, S. heidelberg* and *S. dublin*. In terms of multidrug resistance the most prevalent serovars of epidemiological importance are *S. typhimurium, S. heidelberg, S. dublin* and *S. paratyphi* (Andino and Hanning, 2015). The horizontal transmission of virulence genes in multidrug resistant *Salmonella* strains can increase virulence and invasiveness and it cause highmortality rates (Han et al., 2011).

INDIAN SCENARIO

Emergence and widespread presence of multidrug resistant *Salmonella* species of poultry origin in India is reported by many workers. Suresh et al. (2006) reported incidence of *Salmonella* serovars on eggshell, egg contents and on egg-storing trays of Coimbatore city, Tamil Nadu. *Salmonella* contamination was recorded in 7.5% of the egg-storing trays and in 7.7% of eggs out of which 5.9% was in eggshell and 1.8% in egg contents. *S. enteritidis* was the major serotype followed by *S. cerro*, *S. molade* and *S. mbandaka*. The strains were resistant to ampicillin, neomycin, polymyxin-B and tetracycline. Savita et al. (2007) reported occurrence of *Salmonella* from diarrheic chickens and litter sample in Madhya Pradesh with a prevalence of 8.69% and 3.22%, respectively. Another study revealed 4.82% of chicken eggs were positive for *Salmonella* in North India and all the isolates were resistant to bacitracin, polymyxin-B and colistin (Singh et al., 2010). *Salmonella* was prevalent in a wide range (25-65%) from different parts of chicken meat marketed in Banglore (Ruban and Fairoze, 2011), while 15.91% prevalence of *S. enteritidis* were reported from Namakkal, South India and the isolates were resistant to erythromycin, ampicillin, kanamycin, cephalothin and tetracycline (Maripandi and Al-Salamah, 2010). A prevalence of 2.7% was reported from poultry tissue and egg samples, with isolates belonging to *S. heidelberg*, *S. typhimurium*, *S. ayinde*, *S. essen* and *S. kastrup* from Bareilly (Taddele et al., 2011).

Suresh et al. (2011) reported the prevalence of *Salmonella* serovars in marketed broiler chickens and processing environment in Coimbatore, Tamil Nadu. Analysis of the various body parts of live chicken revealed prevalence rate from 1.4% in cloacae to 6.9% in crop region, while the environmental samples showed higher prevalence upto 16.67%. *S. enteritidis* was the predominant *Salmonella* serotype but other serotypes such as *S. bareilly*, *S. cerro*, *S. mbandaka* and *S. molade* were also encountered (Suresh et al., 2011). Taddele et al. (2012) reported that all the *S. gallinarum* isolates in their study were resistant to erythromycin, while 86.7% were resistant to nalidixic acid and 53% were resistant to kanamycin and tetracycline. Moreover *S. typhimurium* showed maximum resistance against antimicrobials followed by *S. kastrup*. Kumar et al. (2012) found that *Salmonella* isolates (*S. gallinarum*, *S. pullorum*, *S. enteritidis*, *S. typhimurium*) recovered from disease outbreaks in broilers from different regions of Haryana were resistant to multiple drugs.

Singh et al. (2013) reported 3.3% of the environmental samples of layer farms situated in Bareilly, Uttar Pradesh were positive for *Salmonella* and *S. typhimurium* was the predominant serovar from cloacae, while *S. kottbus*, was recovered from cloacae, eggs and faeces and all the isolates were resistant to clindamycin, oxacillin, penicillin and vancomycin. Arora et al. (2013) isolated *S. gallinarum* (84%), *S. enteritidis* (10%) and *S. typhimurium* (6%) from Haryana from poultry and the isolates were resistant nalidixic acid and carbenicillin. Rajagopal and Mini (2013) reported outbreak of salmonellosis in three different poultry farms in Kerala and the serovar responsible for the outbreak was *S. gallinarum*. *Salmonella* were isolated from 6.1% of environmental samples in West Bengal and the isolates were found to resistant to chloramphenicol, ciprofloxacin, gentamicin, levofloxacin, norfloxacin and oxytetracycline (Samanta et al., 2014). A prevalence of 12.28% was documented in Tarai region of Uttarakhand from broilers (Kumar et al., 2014) and the serovars were *S. gallinarum*, *S. enteritidis* and *S. typhimurium*. Jinu et al. (2014) reported total *Salmonella* prevalence rate of 5.88% from chicken in Bareilly, Uttar Pradesh and the major serotypes were *S. typhimurium* and *S. enteritidis*. Ahmad et al. (2014) studied MIC levels of various antibiotics among Indian isolates of *S. typhimurium* and found a resistance of 93% and 57% for sulfisoxazole and tetracycline, respectively. Isolation of *Salmonella* spp. (15.67%) from faecal samples of poultry with diarrhoea was reported from Mizoram also (Lalzampuia et al., 2014).

Eventhough *Salmonella* is the most common foodborne pathogen affecting public health, there are a few reports of its disease occurrence among consumers in India due to poultry products. *S. enteritidis* food poisoning among army personnel due to frozen fowl and gastroenteritis cases from Manglore due to *S. wein* are available (NICD, 2009; Antony et al., 2009).

CONCLUSIONS

Even though there is increase in advance technologies in food production and implementation of better hygiene measures in food processing and handling, there is paradigm increase in incidences of salmonellosis in several parts of the world. The epidemiological complexity of salmonellosis involves horizontal and vertical transmission, fecal excretion, environmental contamination and presence of carriers in different species, making its control difficult to be achieved. Indiscriminate use of antibiotics in feed as growth enhancer contributes selection of resistant strains and may affect human health. Due to the public health issues, the prevention of food borne transmission of *Salmonella* spp. is of utmost priority for the poultry sector. The hygienic and sanitary standards governed by the national and international regulations specify that *Salmonella* species should be absent in 25g of food sample, including poultry meat and egg. For effective prevention and control of foodborne salmonellosis, there should be programmes for creating awareness among consumers about the food safety and guiding the food handlers and animal breeders, mainly of poultry regarding safe production of food starting from farm to the table.

CONFLICT OF INTERESTS

There is no conflict of interests among authors regarding the publication of this paper.

AUTHORS CONTRIBUTION

Jinu Manoj contributed collected the data and wrote the article, while Manoj Kumar Singh contributed to critical revisions of the article and Yesh Pal Singh served as a scientific advisor.

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