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Chapter 2

Salmonellosis in Animals

Serpil Kahya Demirbilek

Abstract

Salmonella has long been recognized as an important zoonotic pathogen of economic importance in animals and humans. The prevalent reservoir of Salmonella is the intestinal tract of a wide range of domestic and wild animals which may conclude in a diversity of foodstuffs of both animal and plant origin becoming infected with faecal organisms either directly or indirectly. In spite of mounting concerns about other pathogens in recent years, Salmonella remains among the leading causes of food-borne disease throughout the world. Lots of both domestic and wild animals are infected by Salmonella spp., mostly harboring the bacteria in their gastrointestinal tracts with no obvious signs of illness. Therefore, Salmonella are usually present in faeces excreted by healthy animals and many times pollute raw foods of animal origin through faecal contact during production and slaughter. The organism may also be transmitted through direct contact with infected animals or humans or faecal contaminated environments. Infected food handlers may also act as a source of contamination for foodstuffs. Because of increasing antibiotic resistance of organism and companion animals, animals are important source of Salmonella infection for human. The organism can be monitored and precautions should be taken regularly by new technological methods.

Keywords: salmonellosis, animals, zoonosis

1. Introduction

Salmonella enterica subspecies enterica can be separated into more than 2400 antigenically different serovars and the pathogenicity of most of these serovars is unspecified. The greater number of incidents of salmonellosis in humans and domestic animals originated from relatively few serovars and these can be separated into three groups on the basis of host prevalence. Host-specific serovars are the first group. These typically result in systemic disease in a small number of phylogenetically connected species. For example, S. enterica serovar...
Abortus ovis, serovar Paratyphi and serovar Pullorum are almost exclusively associated with systemic disease in sheep, fowl and humans, respectively. Host-restricted strains are the second group. These are mainly connected with one or two closely related host species but may also unusually result with disease in other hosts. For instance, *S. enterica* serovar Choleraesuis and serovar Dublin are generally associated with severe systemic disease in pigs and ruminants, respectively [1]. Nevertheless, these serovars are possibly efficient of infecting other animal species and humans. The third group comprises of the extensive *S. enterica* serovars, such as Infantis and Enteritidis that usually induce gastroenteritis to a large extent of unrelated host species. Obviously the nature and rigidity of *Salmonella* infections in different animal species varies hugely and is affected by many factors including the *Salmonella* serovar, dose, age, strain virulence, host animal species, immune status of the host and the geographical region [2].

*Salmonella enterica* subsp. *enterica* remains a main cause of infection and disease in human and animals worldwide. Much of the public health and economic problem originated from diseases or infected animals carriage. In Europe, animal salmonellosis as a cause of human infection became increasingly important as agricultural production started to intensify after World War II. In the 1950s, the rapid intensification of the poultry industry in numerous countries was supported by importation of dried fish meal from South America which comprised many *Salmonella* serovars. So, non-typhoidal salmonellosis is one of the leading causes of acute bacterial gastroenteritis in the USA, responsible for an estimated 1.4 million cases of illness annually. Widespread commercial distribution of contaminated foods can sometimes involve huge numbers of consumers in *Salmonella* outbreaks. For example, a 1994 *S. Enteritidis* outbreak associated with ice cream in the USA affected 224,000 people. *Salmonella* outbreaks can particularly have severe consequences for highly vulnerable populations in facilities such as day care centres and nursing homes [3, 4].

Although the genus *Salmonella* consists of more than 2400 serovars, most human cases of salmonellosis in the USA are caused by 5–8 serovars. United States (US) Centers for Disease Control and Prevention (CDC) reported that approximately 60% of human cases were caused by *Salmonella enterica* ser Enteritidis (24.7%), *S. ser Typhimurium* (23.5%), *S. ser Newport* (6.2%) and *S. ser Heidelberg* (5.1%). These same four serovars represented 46.4% of the isolates from nonhuman sources that year. Also serotypes are changing with time, for example, CDC reported that many of *Salmonella* serotypes decreased in incidence compared with 2012, infections caused by serotype 4, [5],12:i:- continued to rise [5].

*Salmonella* ser Enteritidis infections are mostly seen with fresh shell eggs and egg products, in which the bacteria contaminate the interior essences of the egg through transovarial infection. *Salmonella* ser Enteritidis infects the ova or oviduct of the hen’s reproductive tract, which causes contamination of the albumen, vitelline membrane and possibly the yolk. Internal contamination of the egg’s content performs egg-sanitizing practices, which focus on decreasing pathogen contamination on the eggshell surface, ineffective.

*Salmonella* Typhimurium definitive phage type DT104 appeared in the early 1990s as the dominant type of *Salmonella* spp. Most isolates have chromosomally encoded resistance to
five antimicrobials, specifically sulfonamides, chloramphenicol, ampicillin, streptomycin and tetracycline (R-type ACSSuT). There is sign that some penta-resistant DT104 strains are also evolving resistance to quinolones and trimethoprim [6]. Evidence in Europe indicates that the emergence of DT104 in cattle was the harbinger to its spread to other animals used for food production [2].

Although DT104 is currently the dominant penta-resistant clone of S. ser Typhimurium, many other phage types (DT29, DT204, DT193 and DT204C) of this serovar have also been seen with multi-drug resistance. Understanding the causes that influence the emergence of these prevalent serovars of Salmonella spp. and the factors leading to the distribution and persistence of Salmonella spp. in animals is beneficial for the occurrence of effective intervention strategies to decrease human exposure to salmonellae [7].

Forms of livestock production and movement are varying as the world is changing. Advanced wages in the West conclude in increased production and importation of poultry meat and processed products from countries in South America and Asia. An improved standard of living in many countries is attended by increased meat ingestion, chiefly pork and poultry but also beef and dairy yields. Regulation of meat production in many countries is improving but there are presently large problems of antibiotic resistance which is enhancing a global problem. Poor control and hygiene conclude in the transmission of many microorganisms of which Salmonella is just one. Other changes connected with increasing living standards in world contain the increasing importance of companion animals in people’s lives which are adequately recognized as sources of infection. Correlated to global changes in trade and human populations, improvements in technology have allowed us to obtain an unprecedented understanding of the biology of Salmonella [7].

However, many aspects of Salmonella biology and infection biology remain tantalizingly unresolved after the last 10 years of research, and more than 50 years after Professor Buxton’s book [8] acted, such that the Salmonella should stay the centre of worldwide investigation activity for many more years. In many details the study of this organism is now a global project. Shrinking investigation budgets in the West have been changed with increasing concern in those countries with increasing budgets and where a value of the animal and public health Salmonella problem is increasing [7].

2. Infection in animals

Salmonella infections occur in lizards, snakes and turtles (including tortoises), in birds such as parrots, canaries, finches and pigeons and in mammals such as dogs and cats. They are less common in small caged animals. In dogs, cats and reptiles, infection may be unapparent and salmonellae can be found in the faeces of normal animals. These organisms can live happily in the intestine of some animals. They are called carrier animals. Salmonella infections most often cause enteritis and diarrhoea. The bacteria can also invade the body to cause septicaemia. This invasion results in fever that commonly accompanies the enteritis caused
by *Salmonella* infection. Affected animals are lethargic, do not eat and have diarrhoea. The diarrhoea is often not distinguishable from that caused by other microbes. The diarrhoea may be profuse and normally house-trained dogs and cats may become incontinent and foul the house unintentionally. In birds, the illness can be less apparent and may only be seen as pasting of the vent.

Very young, old or immunosuppressed animals or birds may be severely affected by the dehydration accompanying the diarrhoea, develop septicaemia or even die. Survivors may have diarrhoea for a time, but most go on to recover completely. Any recovering animal may be a carrier for a varying length of time. The organism can live in the gut lining in small numbers and within local lymph nodes, particularly in the lymphoid areas such as the caecum of birds. Persistence inside the animal can lead to reappearance of infection if the animal develops a different disease [9].

3. *Salmonella* infections in the domestic fowl

Four diseases induced by *Salmonella* are significant in poultry; pullorum disease caused by *Salmonella enterica* serovar Pullorum, fowl typhoid (FT) caused by *S. Gallinarum*, paratyphoid caused by several serovars and subspecies of *Salmonella* most particularly *S. Typhimurium*, *S. Enteritidis*, *S. Infantis* to name a few and arizonosis caused by *S. enterica* subsp. *arizonae* [7]. The poultry’s specific *S. enterica* serovars Gallinarum and Pullorum have mostly been eradicated from the industries of Europe and North America. Nevertheless, in parts of the world with less developed industries, and especially in systems with poor biosecurity, these serovars still represent larger threats to bird health and welfare. Even though chickens are the normal hosts of *S. enterica* serovars Gallinarum and Pullorum, natural outbreaks induced by these serovars have been explained in turkeys, guinea fowl and other several species. There are many sources of infection in poultry containing vertical transmission, contaminated feed and the environment. Asymptomatic excreting of *Salmonella* from the intestine causes the contamination of eggs concluding in vertical transmission. As soon as after hatching, oral intake by the chicks results in very high numbers of *Salmonella* in the gut and great shedding in the faeces. This causes rapid horizontal spread around the hatchery [2].

Domestic fowl compose one of the largest reservoirs of *Salmonella* and is significant as a risk to public health through consumption of polluted eggs and meat. Arizonosis caused by *S. enterica* subsp. *arizonae* is an egg-transmitted infection mainly of young turkey poultries that still happens sporadically in commercial flocks and which may as well infect and unusually induce disease in chickens or other species of birds. Reptiles can be a reservoir of *S. arizonae* for birds and for man. The bacteria to place in the ovary and oviduct of breeder turkeys and the poults hatched from infected breeders develop disease. The disease is described by diarrhoea with pasting of faeces in the vent, huddling near the heat source, anorexia and boosted mortality sometimes accessing 50% [10].
4. *Salmonella* infection in poultry

Poultry products are frequently identified as important sources of *salmonellae* that cause human illness. An estimated 182,060 Americans became infected with *S. Enteritidis* during 2000 after consuming contaminated eggs [11]. Approximately 80,010 of *S. Enteritidis* outbreaks occurring in the USA between 1985 and 1999 with an identified food source were attributed to eggs [12]. Eating contaminated chicken has also been identified as a significant risk factor for *S. Enteritidis* infection [13]. Illustrating the importance of poultry as a reservoir for the transmission of *salmonellae* to humans, many of the serotypes that are most prevalent in humans (such as *S. Typhimurium* and *S. Enteritidis*) are also found common in poultry [4].

The ability of *Salmonella* to cause disease in poultry is closely related to the infecting serovar and the age and genetic background of the bird. Fowl typhoid (FT) is a disease caused by *S. enterica* serovar Gallinarum that is usually transmitted by the oro-faecal route and mainly affects adult birds [2]. The first described outbreak of FT was characterized by high mortality, especially during the first 2 months of the outbreak [7]. The pullorum disease (PD) is caused by *S. enterica* serovar Pullorum, is egg transmitted and occurs primarily in the first few days of life, high numbers of dead-in-shell chicks are seen (white bacillary diarrhoea). The ability of serovars other than Gallinarum and Pullorum to cause disease is relatively poorly understood [2].

Poultry may be infected with a wide variety of *Salmonella* serovars with the infection largely confined to the gastrointestinal tract with faecal excretion [7]. *S. enterica* serovar Typhimurium is primarily known for producing clinical salmonellosis in very young birds. Mortality rates vary enormously, from less than 10% to more than 80% in severe outbreaks. Resistance to infection develops rapidly over the first 72 hours of life and has been attributed to maturation of macrophages and the development of a commensal flora in the gut leading to competitive exclusion of *Salmonella* [7]. Strains of *S. enterica* serovar Enteritidis are also highly virulent for young chicks [14]. *S. enterica* serovar Enteritidis, and in particular strains of phage type 4 (PT4) can also cause asymptomatic and chronic infections in older birds including commercial layers and broiler breeders [15–17]. Epidemiological data demonstrate a clear association between food poisoning caused by serovar Enteritidis PT4 and the consumption of undercooked eggs [18]. The extent to which egg contamination occurs before or after egg formation is unclear [2].

Many *S. enterica* serovars have been associated with food poisoning in humans, however the potential for such serovars to infect poultry has been little studied in controlled experiments. A chick isolate of *S. enterica* serovar Kedougou colonized the gut, but did not intrude on the mucosa of tentatively infected day old chicks [19]. Likewise, strains of serovars Heidelberg, Senftenberg, Infantis, Montevideo and Menston all expeditiously colonized the intestines of youth birds, but were less invasive than a strain of serovar Typhimurium [20]. Lately, the virulence of various different serovars of *Salmonella* was evaluated in day old specific pathogen-free chicks. The host-specific serovar Pullorum affirmed to be the most virulent, pursued by the omnipresent serovars Typhimurium and Enteritidis. Three out of the four strains of serovar Heidelberg made low levels of mortality, whereas birds infected with isolates of Kentucky, Hadar and Montevideo all lived. Nevertheless, these latter serovars all colonized
the intestines expeditiously and caused a reduction in body weight, showing that subclinical Salmonella infections can even be harmful to bird health, welfare and productivity [21]. The reasons why such serovars are clearly much less virulent in chicks, yet retain the ability to induce human food poisoning are not seen [2].

5. Salmonella infections in cattle

Salmonella infections are an important cause of mortality and morbidity in cattle and subclinically infected cattle are frequently found. Cattle thus constitute an important reservoir for human infections. There have been numerous reviews over the years [22] increasingly reporting about multi-drug resistant strains [23] as well as the importance of Salmonella for the food industry. Interestingly, despite decades of research into salmonellosis, the disease and its public health consequences are not really resolved [7]. Salmonellosis occurs worldwide in cattle and has been associated primarily with serovars Dublin and Typhimurium. Other serovars are sporadically associated with bovine infections [2]. During the period 1968–1974, Sojka et al. [1] recorded the isolation of 101 different Salmonella serovars, usually at a low prevalence, detected annually in cattle [7]. Salmonellosis reached a peak in the British cattle industry in the 1960s with over 4000 incidents in 1969 [1, 2]. In the USA, 48% of the 730 Salmonella, other than S. Dublin and S. Typhimurium, isolated from cattle were represented by 7 serovars [24]. In the UK, in 2009, there was 10 Salmonella reports of non-GB origin reported from cattle, these included S. Typhimurium DT104, S. Mbandaka, S. Anatum and S. Dublin, clearly showing that importation of new strains remains a constant risk [7].

In the recent times, there has been a sharp reduction in the number of Salmonella outbreaks and over the last 5 years there have been only 400–500 cases annually, with similar numbers of events caused by S. enterica serovar Typhimurium and serovar Dublin in adult cattle and calves. S. enterica serovar Dublin and serovar Typhimurium are endemic in northern Europe, despite the divisions of these serovars vary. The origin of most outbreaks of salmonellosis in cattle is possibly faecal to oral contact. Infected cattle may excrete up to 108 CFU Salmonella/g of faeces and pollution of the environment in the nearness of other animals is a potent source of infection. Subclinical discharge of Salmonella aggravates the problem of pollution. Cattle that discharge an active Salmonella infection but show no clinical symptoms (often convalescing animals) are known as “active carriers”. These may spread Salmonella constantly in quantity greater than 105 cfu/g of faeces and thus can be determined by routine bacteriological examination. Active carriage is commonly the sequel to clinical enteritis or systemic infection, and infected animals may excrete Salmonella for years or as well for life. “Passive carriers” are immunized animals that swallow Salmonella with feed and subsequently pass them in their faeces with no active infection of the intestines. Hence, when eliminated from a dirty environment these animals will stop excreting Salmonella. “Latent carriers”, Salmonella remains subclinically in the tissues but is just randomly excreted in faeces [2]. Excretion may be initiated by stress, for example, at parturition. Understanding the biology of this true “carrier state” is likely to be key to ultimately controlling this important pathogen in cattle and may also provide insight into, for example, the asymptomatic carriage of S. enterica serovar Typhi by humans [7].
Salmonella - A Re-emerging Pathogen
Author details

Serpil Kahya Demirbilek

Address all correspondence to: serpilkahya@uludag.edu.tr

Department of Microbiology, Faculty of Veterinary Medicine, Uludag University, Bursa, Turkey

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