Salmonellosis in Dairy Cattle

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Abstract

Salmonellosis in dairy cattle is an emerging public health threat responsible for significant economic losses globally. The disease, caused by various serotypes of *Salmonella enterica*, affects cattle of all ages and poses zoonotic risks, particularly to farm workers and veterinarians. The global expansion of the dairy industry to meet increasing population demands has been hindered by the persistent threat of salmonellosis. The infection's prevalence and serotype distribution vary widely across geographical regions, with important serotypes including *S. Typhimurium*, *S. Dublin*, *S. Newport*, and *S. Cerro*. Certain serotypes, such as *S. Dublin*, are host-adapted to cattle and can cause severe systemic infections, reproductive losses, and pneumonia in young calves. In contrast, others are capable of infecting multiple host species, complicating control measures. The long environmental survival of specific strains, such as *S. Newport*, and the development of multidrug resistance further exacerbate the problem. Clinical impacts include reduced milk and meat production, stillbirths, and abortions. While antibiotics are sometimes necessary, their use is controversial due to the risk of antimicrobial resistance; therefore, fluid therapy remains the cornerstone of treatment. Control strategies focus on vaccination, stringent hygiene practices, isolation of infected animals, and effective farm management to mitigate transmission. Although complete eradication remains difficult, these measures significantly reduce the burden of salmonellosis in dairy cattle.

Keywords: Salmonella, Cattle, Zoonosis, Antimicrobial resistance, Disease control, Farm Management

Cite this Article as: Ali U, Rehman MU, Chandni P, Arooj A, Fatima UR, Hassan MU, Abbas S, Meraj MT, Tehreem A and Ahmed I, 2025. Salmonellosis in dairy cattle. In: Ismael SS, Nisa QU, Nisa ZU and Aziz S (eds), Diseases Across Life: From Humans to Land and Sea. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 31-38. https://doi.org/10.47278/book.HH/2025.346

A Publication of Unique Scientific Publishers

Chapter No: 25-005

Received: 25-Feb-2025
Revised: 14-Apr-2025
Accepted: 25-May-2025

Introduction

Dairy cattle are an essential component of livestock sector, providing livelihood to millions of farmers worldwide and produce essential necessities like milk and meat. However, dairy herds constantly face challenges to their health and productivity by a number of infectious diseases, among them salmonellosis holds particular significance. Salmonellosis caused by bacteria of the genus Salmonella is an extremely contagious disease affecting cattle of all ages with young calves being particularly susceptible. Salmonella is a rod-shaped, gram negative, facultative anaerobic bacteria and often opportunistic pathogen that belongs to the family of Enterobacteriaceae. There are 2 most common species of Salmonella genus: *S. enterica and S. bongori*. Salmonella *enterica* subspecie Dublin is host-adapted to cattle and can cause clinical problems in dairy cattle (Holschbach & Peek, 2018). Consuming raw milk from infected cows led to severe illnesses in humans, particularly in immunosuppressed individuals. Infected people can develop septicemia, osteomyelitis and meningitis (McDonough et al., 1999). Salmonella infection in calves typically involves the invasion of intestinal mucosa. *Salmonella* infects the gastrointestinal tract of various animals, potentially causing acute enteritis, asymptomatic infections, and systemic spread affecting the reproductive system in pregnant mammals. These infections can be more severe in young animals (Wallis & Barrow, 2005). *Salmonella* Dublin infection in young calves can cause pneumonia. These infections commonly undergo fecal-oral transmission with contaminated environment, food and water contributing to an increased spread of the bacterium (Torreggiani et al., 2024). *S.* Dublin is a zoonotic bacterium and can cause severe illness, hospitalization and death of farm workers and veterinarians. Salmonella pathogenicity island, toxins, flagella, fimbriae and virulence plasmid are virulence factors of Salmonella that make it harmful and contagious (Holschbach & Peek, 2018; Velasquez-Munoz et al., 2024). The objective of this chapter is to provide a comprehensive overview of salmonellosis in dairy cattle, focusing on its epidemiology, pathogenesis, diagnosis, and effective strategies for prevention and control.

Etiology

Salmonella poses a significant public health threat due to its adaptability and virulence. *Salmonella enterica,* a prominent species within the Salmonella genus, is further subdivided into six distinct subspecies. *S. enterica* sub-species enterica is most commonly found in dairy cattle. Salmonella contains more than 2500 Serovars that can be differentiated based on their antigen composition. Serovars are determined by the somatic(O), flagellar(H), and capsular (Vi) antigens (Malorny et al., 2004). The outcome of Salmonella infection varies depending on three factors: the infective dose, host related factors, and immunity level (Kemal, 2014). *Salmonella* Dublin, a strain of *S. enterica*, can cause enteritis and septicaemia in cattle, leading to severe gastrointestinal symptoms and potentially life-threatening systemic infections. Animals can become infected with *S.* Dublin through the ingestion of faeces, body fluids, or contaminated environmental sources. Infection occurs mainly via ingestion of contaminated milk, saliva, nasal secretions, feed, or water. Oral transmission is the most common route of infection for *S.* Dublin (Velasquez-Munoz et al., 2024). Vertical transmission of *S.* Dublin is evident, where the bacteria is passed from the mother to the foetus during pregnancy. This can lead to devastating consequences, including abortion in the final trimester of gestation or the birth of a congenitally infected calf (Hanson et al., 2016). Recent research has identified three key genetic loci—*aroA*, *invH*, and the *spv* operon—that work together to enhance S. Dublin's virulence by evading host immune responses and colonizing the gastrointestinal tract (Tsolis et al., 1999).

- Important Serotypes of Salmonella in Dairy Cattle
  Different serotypes of Salmonella are involved in health deterioration of the Dairy Cattle. The most important serotypes include;

1. *Salmonella* Dublin

Salmonella Dublin is considered host-adapted to cattle commonly affecting young and adult cattle. It is one of the most prevalent serotypes in dairy farms in the US, Canada, Germany, and the UK (Parolini et al., 2024; Velasquez-Munoz et al., 2023). According to a study from 1996 to 2013 in the US, *S.* Dublin had a 43% higher Multidrug-resistance prevalence than other isolates (Velasquez-Munoz et al., 2023). Direct oral uptake from contaminated food and water are common source of infections. Due to transplacental transmission, it can cause stillbirths and abortion in some cases. The infectious dose of more than 10^6 CFU orally can result in clinical symptoms and faecal shedding in young calves. The pathogenesis of *S.* Dublin is considered associated with virulence plasmid genes (spv genes) (Nielsen, 2013). Each serotype has a unique virulence plasmid but an 8kb spv regulon is a highly conserved region in all plasmids. The spv regulon comprises of spvR regulatory genes and spvABCD structural genes (Fierer et al., 1993, Passaris et al., 2018). The study on bovine hosts proposes that SPV genes enhance the proliferation of *Salmonella* Dublin in the intestinal tissues as well as in extraintestinal sites. Mostly the target sites for replication of this serovar are phagocytic cells and epithelial cells (Libby et al., 1997). Due to the ability of *S.* Dublin to cause asymptomatic infections and the development of a latent carrier state of disease, its prevalence is underestimated internationally (Kent et al., 2021). *S.* Dublin organisms ingested by cattle can pass through the gastrointestinal tract with little or no possible invasion of the mesenteric lymph nodes. The healthy animals can be positive for Salmonella by rectal swabs in the presence of active carriers. Richardson described such animals as "passive carriers". The presence of latent carriers which harbour localized infections but do not shed Salmonella in faeces goes undetected during investigation. In an epidemiological investigation of 600 cattle for *Salmonella* Dublin in a separate study revealed 14 out of 59 i.e. 24% were infected at post-mortem examination. These cattle were negative with rectal swabs. In this way, latent carriers interfere with the results of disease prevalence (Wray & Sojka, 1977).

2. *Salmonella* Typhimurium

Salmonella Typhimurium is commonly linked to enteric diseases in calves, but it has a wide host range in animals (Parolini et al., 2024). The strain is named as host "generalists" due to its prevalence in multiple hosts. *Salmonella* Typhimurium have four MDR phenotypes. It includes ASSuTe phenotype (ampicllin, streptomycin, sulfonamides, tetracycline resistant phenotype), expanded version of ASSuTe with additional resistance to aminoglycosides, AKSSuTe (ampicllin, kanamycin, streptomycin, sulfonamides and tetracycline resistant phenotype) and extended version of AKSSuTe with resistance to cephalosporin (Brichta-Harhay et al., 2011). Multidrug-resistant (MDR) phage type 104(DT104) of *Salmonella* Typhimurium is a public health concern mainly reported in the United States. Cattle infected with this serotype pose a significant threat to other farm animals. It is resistant to ampicillin, sulphonamides, tetracycline, chloramphenicol, and streptomycin antibiotics (Wells et al., 2001). The combination of prolonged environmental survival and MDR genes makes this strain difficult to eradicate from the farm, once infected (You et al., 2006). Due to its zoonotic nature, the *Salmonella* Typhimurium DT104 strain can be transmitted to humans through raw milk or other milk products. Humans, once infected by contaminated beef or milk with this strain, have twice the hospitalization rate than other foodborne illnesses associated with salmonellosis (Gutema et al., 2019). Many other serovars have also emerged, one of them including the monophasic variant of *S.* Typhimurium, whose antigenic formula is 1,4,[5],12:i:-. It is multi-drug resistant and actively involved in animal and human infection. Its high transmission capacity can cause global health hazards. The tolerance for heavy metals might be an important factor behind the prevalence of its clones. Furthermore, it has been found that genes providing heavy metal tolerance to this serotype may coexist with its antibiotic-resistant genes. This ability can further promote its co-dissemination and resistance. A study shows *S.* 1,4,[5],12:i:- evades the host defence system using copper which is key for macrophage defence against Salmonella infections. This mechanism i.e., metal-mediated pathogenicity provides additional benefit to the pathogen (Sun et al., 2020).

3. Other Serotypes

Salmonella Cerro is one of the emerging pathogenic serotypes of *Salmonella enterica*. Although its prevalence is less reported. According to a study conducted in the United States, *Salmonella* Cerro was 0.2% prevalent as compared to *Salmonella* Typhimurium which accounted for 19%. Laboratory verified human cases accounted for 0.1% of the cases in the 2005 and 2006 period (Cummings et al., 2010).

Salmonella Newport is another important serotype of *Salmonella enterica*. It has a significant mortality rate in both adult and young animals. This serotype has also developed drug resistance. The resistant phenotypes were dominated by MDR-AmpC phenotype. It has the ability to infect multiple hosts (Brichta-Harhay et al., 2011). Multi drug-resistant *S.* Newport has a long incubation time of 26 weeks in manure. The time can go beyond 47 weeks in manure-amended soils. The survival time may vary with respect to natural environmental conditions (Toth et al., 2011). *Salmonella enterica* serotype Bredeney is a non-host specific serotype, sporadically detected in dairy cattle. Although it is more common in poultry yet its infections were detected in cattle as well raising health concerns (Torreggiani et al., 2024). *Salmonella enterica* serovar Enteritidis is a foodborne zoonotic pathogen that affects dairy cattle. Although this serotype does not cause serious health complications yet it can cause foetal loss if left untreated. The pathogen can cross blood into the placenta, thus causing vertical disease transmission (Liu et al., 2023).

Pathogenesis

The infection of Salmonella spp. is recognized by its ability to infect the gastrointestinal tract, and lungs and also causing septicaemia and abortions in cattle (Holschbach & Peek, 2018). Salmonella spp. can infect animals of different ages but the highest mortality rate is reported in young. Clinical signs in calves usually appear between 10 and 90 days of age. The calves show three types of infection per acute (septicemic), acute and chronic (Rings, 1985). The factors by which the pathogenesis of this bacteria is determined are the load of bacteria in the host, the host's conditions (i.e., immune-competent or compromised), type of infecting serovar, age, stress conditions, and the immune system's response against these bacteria (Nielsen & Nielsen, 2012). One of the potential target sites of Salmonella infections in cattle is the lymphatic system, specifically the lymph nodes (LN). It is because lymph nodes perform filtering mechanisms to sequester agents for eventual destruction by lymphocytes. However, certain intracellular bacteria, such as Salmonella, can evade the body's defence processes and instead survive within macrophages. Salmonella spp. has been detected in the lymph nodes of the infected hosts (Edache et al., 2024). *Salmonella* Dublin, once enters the host multiplies in the gastrointestinal tract and manages to attach mucosal wall of the small intestine and thus disturbs normal microflora. It produces enterotoxins to destroy enterocytes and activate inflammatory or immune responses. It is disseminated throughout the body when macrophages try to engulf it. The bacteria primarily target lymphatic tissues from where it migrates through M-cells to payers' patches as well as mesenteric lymph nodes. From these sites, bacteria spread to the lymphatic system and cause bacteraemia. *Salmonella* Dublin first colonizes in the digestive system and then in mesenteric lymph nodes and then disseminates in the body. In this case, intestinal inflammatory action remains ineffective in preventing the infection from spreading systematically. The immune system of the host is activated by detecting microorganisms through specific receptors. In the case of Salmonella, these receptors recognize lipopolysaccharide and components encoded by Salmonella Pathogenicity Islands (SPIs) (Abuelo, 2024; Holschbach & Peek, 2018). These pathogenic islands have virulence genes present in the bacterial chromosomes, called virulence plasmids. There are 17 such pathogenic islands are discovered and all different bacteria have specific pathogenic island, but the most virulent Salmonella pathogenic islands are SPI 1 and SPI 2 (Kombade & Kaur, 2021). SPI 1 encodes type three protein secretion system, through which the effector protein reaches the host cell. In case of cattle, it delivers effector protein in intestinal cells causing invasion and enteritis in cattle (Lou et al., 2019). Salmonella pathogenicity islands SPI-1 and SPI-2 contain genes responsible for intestinal inflammation and intracellular survival, respectively (Ohl & Miller, 2001). It colonizes the intestine of the host which is indicated by the shedding of bacteria through the faeces for a prolonged period, so it is mainly linked with enteric fever (Wallis & Barrow, 2005). In order to develop acute infections, enough number of bacteria must be present. Many experimental conditions on infectious dose revealed that *Salmonella* Typhimurium infections can occur with high bacteria number of almost 10^8 to 10^{10} organisms. The cattle affected with low bacterial count usually exhibits no clinical symptoms of infection. The infection route involving conjunctiva is found more effective in developing infection than oral route. This shows the relation between bacterial load in developing acute infection (de Jong & Ekdahl, 1965). The zoonotic nature of Salmonella and its possible route of transmission can easily be understood by the following diagram. (Fig. 1).

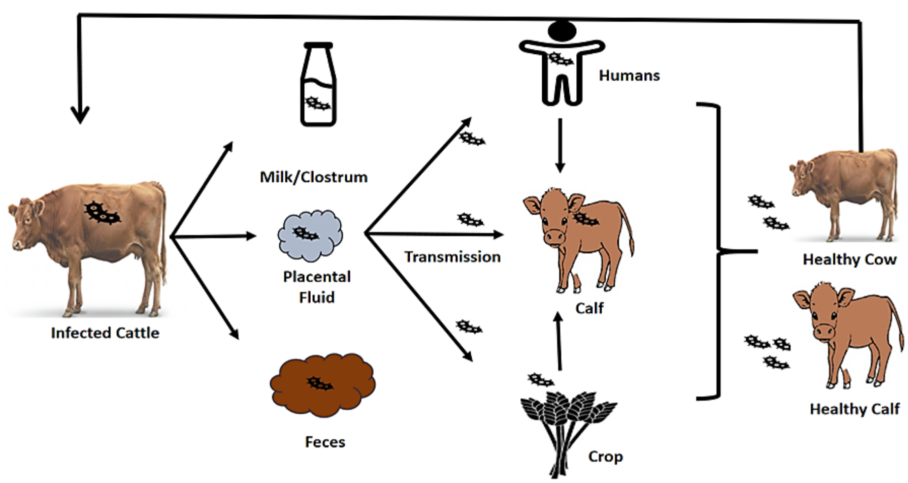

Fig. 1: Transmission of *Salmonella Spp.* to animals and humans

Diseases and Clinical Infections

Salmonella spp. is involved in many diseases and clinical infections in dairy cattle. The symptoms of Bovine Salmonellosis may include anorexia, diarrhoea, dehydration, fever and abortion. Following infection by Salmonella spp. cattle may show watery diarrhea and hematochezia. The ultimate result of this is weakness and dehydration. In severe cases, death can occur. Salmonella spp. infects wide range of body organs. The gross lesions post infection can result in enlarged spleen, hepatomegaly, haemorrhagic enteritis, abomasitis and mesenteric lymphadenitis (Torreggiani et al., 2024). Salmonella infections can cause enteric, septicemic, and reproductive diseases in the adult cattle. Reproductive losses are mainly associated with female sexually mature cattle. In calves, respiratory distress is observed such as calves infected with *Salmonella* Dublin are mostly affected with pneumonia. Enterocolitis can occur due to maldigestion and malabsorption during infection phase further worsening the cattle health. Fresh blood in the faeces can be observed post colon inflammation (Holschbach & Peek, 2018).

Studies have shown that calves are more vulnerable to Salmonella infection in which it commonly causes enteric disease. The infection can spread to other organs depending on the host immunity and strain' virulence factors. Post infection symptoms may include lethargy, hyperthermia and profuse diarrhea. The gross pathological findings may include fibrino-necrotic enteritis, edema of mesenteric lymph nodes, enlargement of liver and spleen, post mortem study revealed macroscopic lesions such as fibrino-necrotic enteritis, hepatomegaly, splenomegaly and oedematous mesenteric lymph nodes (Ramos et al., 2019: Nikkah et al., 2023: Pharo et al., 2025).

Epidemiology

Salmonella is a worldwide health concern. The severity of the infection depends on the host and bacterial factors. Multiple factors affect its incidence rate which includes; population size, weather conditions, hygienic conditions and management. Its prevalence varies in every country. It is moderately prevalent in dairy cattle in Southern Ethiopia i.e., 9.3% (Asefa et al., 2023). Due to its zoonotic nature, in the United States, it causes estimated illnesses of 1.4 million and 400-600 deaths annually (Cummings et al., 2010). *Salmonella enterica* can transmit vertically from dam to foetus. In a study, Salmonella was recovered from neonates as young as one day old through the rectal swab (Hanson et al., 2016). Environmental conditions, farm management, and national surveillance programmes play critical roles in influencing the spread and survival of *Salmonella* spp. in dairy herds (Hofer et al., 2024).

The incidence of Salmonella infections in dairy cattle varies with different seasons and geographical areas. A cross-sectional study conducted between December 2021 and May 2022 in the Boloso Sore district of Southern Ethiopia showed the prevalence of 9.3% in fresh milk samples, with significant variations among specific kebeles: Areka 02 (3.2%), Legama (16.7%), Tadisa (8.7%), and Wormuma (9.1%). These findings lead to a probable geographical radius of infection prevalence by localized management and environmental cleanliness.

Climate characteristics of the study area, characterized by an average annual rainfall of 1300 mm, a mean daily temperature of 20.4°C, and two distinct wet seasons (March–May and June–September), could support the survival and spread of bacteria by creating an environment favourable for the growth of salmonella during wet seasons. These seasonal variations, like high moisture and humidity during rainy seasons, contribute to the spread and survival of the pathogen. Therefore, it is important to consider the effects of season and geographical area while planning a way to control the infection of Salmonella, because by considering these factors, one can make a more effective control strategy (Asefa et al., 2023).

Transmission

Salmonella can be transmitted through oral-faecal route, contaminated food and water. The main routes for the transmission of Salmonella infections in cattle are oral. It can cross the placenta in pregnant cattle, resulting in vertical transmission (Hanson et al., 2016). Asymptomatic cattle can shed *Salmonella* in faeces, milk, and colostrum. Some *Salmonella enterica* serovars can survive in aerosols for a long time. These serovars can infect via inhalation of pathogens (Wathes et al., 1988; Liu et al., 2023).

Some serotypes which are involved in vertical transmission such as *Salmonella* Enteritidis, can colonize the mammalian uterus. They colonize the intestinal tract and then invade the dendritic cells and macrophages in the intestinal epithelial cells. These serotypes can evade the host defence mechanisms and survive inside the macrophages. *Salmonella* Enteritidis can form vacuoles after entering macrophages. From here bacteria is transported to mesenteric lymph nodes and some of them enter the placenta and colonize. The foetus becomes infected in pregnant animals (Liu et al., 2023). While transmission via bull semen remains unconfirmed, a recent study isolated MDR *S. Dublin* from cryopreserved semen of a Holstein bull (Bentum et al., 2025).

Many factors contribute to the increased transmission of the bacteria. Overcrowding, poor hygiene, cattle trading, use of infected slurry, poor biosecurity for farm visitors, sharing of equipment and stressful conditions increase the chances of transmission. In crowded farms, Salmonella spp. can easily be transmitted through direct contact with infected animals or through contaminated food or surfaces (Fabri et al., 2024).

Public health concerns arise because Salmonella is transmitted to humans through unpasteurized milk, beef, and beef products, especially in areas where raw or unpasteurized milk is used. The risk is higher because of the contamination that can happen during slaughtering and food processing when proper hygiene is not maintained. These issues highlight the importance of encouraging the pasteurization of milk to kill harmful bacteria and raising awareness among dairy farmers and consumers about the dangers of consuming unpasteurized milk and other dairy products (Gutema et al., 2019: Asefa et al., 2023).

Risk Factors

The Risk factors associated with salmonellosis in dairy cattle includes host factors and environmental factors. The host factors include breed, age of the animal, number of prior births, body conditions and the lactation stage. Animals with poor body conditions and with late lactation stage have more prevalence of Salmonellosis. Along with the environmental influences, several animal-level factors are significantly related with Salmonella prevalence. In comparison to younger individuals, older cows, especially cows above 9 years, are more at risk for infection (Asefa et al., 2023). The non-host factors or environmental factors associated with Salmonellosis in dairy cattle are food and water safety, biosecurity risks (include farm workers and wildlife), Hygienic environment, shelter conditions, animal spacing and fencing etc.

The study conducted in China revealed wildlife, particularly rodents and birds in sheds and feed storage areas, as the major biosecurity risk factor promoting disease in dairy cattle. Sharing PPE and other food-handling equipment can also pose a great biosecurity risk. Moreover, migratory birds may serve as reservoirs for extended-spectrum β-lactamase (ESBL), antibiotic-resistant enteric bacteria (Wang et al., 2023). Many stressful conditions like sudden changes in the feed of animals, transportation, poor administration of drugs, and inappropriate antibiotics are the factors that increase the risk of disease in cattle (Abuelo, 2024). The other environmental risk factors are weather conditions, feed and water quality, manure management practices, housing conditions (In housing conditions few factors are included; ventilation, bedding conditions, overcrowding, herd size and spacing), screening and isolating sick animals and large herd size. These Risk factors increase or become more serious, particularly in rainy seasons when flooding can carry pathogens into water sources and feed supplies. It is a hypothesis that the entrance of new animals into the herd, visitors and more than 4 calves in a single pen are the factors that increase the risk of Salmonella (Perry et al., 2023). Salmonellosis is a food and waterborne disease; therefore, weather conditions like hot weather and precipitation, which support the growth of Salmonella, increase the risk of disease transmission (Morgado et al., 2021). Contaminated food and water are the main risk factors through which the disease is transmitted. Food becomes a risk factor when we use contaminated crops for which animal manure is used as fertilizer and the water becomes contaminated by animal faeces (Castañeda-Salazar et al., 2021).

Diagnosis

Diagnosis of Salmonellosis involves isolating the organism from samples such as faeces, blood, tissue specimens, rectal swabs, environmental samples, food products and feedstuffs (Abuelo, 2024). Oral secretions and blood culture methods are less accurate than faeces culture for isolating the organism and require attentive handling to avoid contamination (Gesessew et al., 2021). To check multidrug-resistant bacteria, faecal samples are subjected to laboratory testing, by initial incubation in tetrathionate broth and then on xylose lysine tergitol agar plates. Further to confirm Salmonella, sheep blood agar can be used (Pereira et al., 2019). Bismuth sulphite agar is also a selective media used to isolate *Salmonella enterica* and mainly its serovar Typhi, but it takes a long time period for the isolation of Salmonella (Park et al., 2012). Salmonella makes green to black colonies and has a brown-black to black zone on BSA, reflected by light. It gives a metallic sheen which distinguishes it from other bacteria (Allen et al., 1993).

A sensitive and rapid method for detecting Salmonella genetic material is the polymerase chain reaction test (PCR) or real-time PCR (Goodman et al., 2017). PCR-based detection of both species-specific (*S. enterica*) and individual serotyping is present in some laboratories for diagnosing Salmonellosis infections, including gastrointestinal and respiratory illnesses. These serotype tests are associated with biological samples including faeces, milk, tracheal and bronchoalveolar lavage fluid. Some serovars of Salmonella can be detected via milk and colostrum of sick animals i.e. *Salmonella* Dublin, *Salmonella* Typhimurium and *Salmonella* Newport serovars (Holschbach & Peek, 2018). Detection through milk is also a good way because milk serves as an excellent medium for many microorganisms including Salmonella due to its rich nutrient content and high-water activity (Gebeyehu et al., 2022)

Enzyme-linked immunosorbent Assay (ELISA) detects immunoglobulins (antibodies) against the LPS O- antigen from serum, milk, and bulk tank milk (BTM) samples (Velasquez-Munoz et al., 2024). However, vaccination may reduce the accuracy of these serological tests (FARZAN et al., 2007). The antimicrobial susceptibility tests include disk diffusion tests on Mueller-Hinton agar. Usually, the antibiotics susceptibility against these antibiotics is checked which include ampicillin, chloramphenicol, tetracycline, streptomycin, and sulfisoxazole are used (Tamada et al., 2001). Moreover, many biochemical tests including Urea agar slants, Motility Indole Ornithine (MIO), Citrate, O-Nitrophenyl-β-Dgalactopyranoside (ONPG), Lysine Iron Agar (LIA) and Triple Sugar Iron (TSI) agar slants (Gebeyehu et al., 2022). Lateral flow assays (LFAs) are diagnostic tests used to detect bacteria in food products such as Salmonella (Silva et al., 2023). Molecular detection of Salmonella is based on DNA extraction, PCR amplification and Electrophoresis of PCR products. These are rapid and reliable methods that are associated with the latest innovations in genetic detection technology and food microbiology (Malorny et al., 2004).

Management and Control

Management is essential for controlling and preventing the spread of bacterial infections to other organisms. It helps minimize the risk of disease, reduces economic losses and maximizes benefits. Management practices include isolating sick animals and treating them separately. Farm workers should maintain good hygiene. They should disinfect all surfaces, food handling equipment, personal protective equipment, boots and hands every time they enter the shed. Daily cleaning of manure, routinely replacing (usually once a week) bedding material for calves, keeping a maximum of 3 to 4 calves per pen and proper quarantine of new animals in separate areas rather than calves' pens are also protective factors against this infectious disease (Perry et al., 2023). Keeping track of the withdrawal period of drugs is a good management strategy for the control of antimicrobial resistance (Pereira et al., 2019). The studies showed that the multidrug-resistant strain of *Salmonella* Newport could not survive for 24 hours at 64°C temperature. However, survival time is also significantly influenced by the environment. Manure exposed to more than 45°C temperature for at least 3 days minimized the presence of Salmonella bacteria, but it is a challenging approach in large farms with modern manure handling systems (Holschbach & Peek, 2018).

Bacterins, live attenuated, and recombinant vaccines enhance immunity against *Salmonella*, though conventional vaccines offer limited protection in multi-serotype environments. Modified live vaccines, like the Dam-deficient *S. Typhimurium*, provide cross-protection against multidrug-resistant *S. Newport* (Mohler et al., 2008). Vaccinating calves (>2 weeks) and dams improves calf immunity via colostrum (Smith et al., 2014). Herd vaccination, combined with good management, remains essential to control *Salmonella* in dairy cattle.

Conclusion

In conclusion, Salmonella species are among the most significant pathogens affecting dairy industry. Calves are particularly susceptible due to their immature immune system, often resulting in serious health complications. In contrast, adult cattle typically exhibit mild or no symptoms, becoming asymptomatic carrier. Infected animals often experience reduce milk and meat production, posing economic challenges. The emergence of multidrug-resistant strains presents a serious public health concern. Its prolonged survival in the environment make eradication difficult. Vaccines can be given as a prophylactic treatment to minimize the infection. Effective control measures include the implementation of standard operating procedures of farm management, training of the farm personnel, regular disease surveillance and proper disposal of the farm waste. Veterinarians should develop targeted treatment plans to prevent the misuse of antibiotics and curb resistance. Overall, adopting stringent biosecurity practices and routine pathogen monitoring are essential to controlling the spread of *Salmonella* in dairy herds.

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