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Article

A Study of The Effect of Certain Environmental Conditions on Salmonellosis

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Abstract: Our research indicates that Salmonella infects various types of buffalo worldwide, including in Iraq. This research also demonstrates that Salmonella is sensitive to antibiotics used in treatment, and some strains are resistant to Ampicillin. Furthermore, Salmonella infection causes economic losses due to animal deaths if left untreated Salmonella bacteria can ferment sucrose and lactose and are capable of producing hydrogen sulfide gas. They also cause food contamination with bacterial pathogens, with Salmonella accounting for 31% of deaths from these infections. Salmonella is a Gram-negative, facultative aerobic bacillus. It is motile by means of peripheral flagella, and its growth is less at a temperature ranging from 35-37 degrees Celsius. Salmonella is a transmissible disease (common between humans and animals). It is widespread in advanced industrial countries and is one of the causes of relatively common diarrhea. It is one of the most common diseases and infections in the pelvic tract and causes specific diseases in birds. Therefore, all members of the Salmonella genus are considered pathogenic.

Keywords: : Salmonellosis, epidemiology, degrees Celsius, facultative, hydrogen sulfide gas

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1. Introduction

Salmonellosis remains an important zoonotic and foodborne disease because Salmonella can circulate among animals, food products, water, people, and the wider environment. Human infection commonly follows ingestion of contaminated food or water, although direct contact with infected animals and fecally contaminated environments also contributes to transmission. The World Health Organization describes non-typhoidal Salmonella as a major cause of diarrheal disease and emphasizes that infected animals may shed the organism without obvious clinical signs [1]. Current public-health guidance likewise highlights food, water, animals, and cross-contamination as major exposure pathways [2].

Members of the genus Salmonella are Gram-negative bacilli within the family Enterobacteriaceae. They are generally motile by peritrichous flagella, facultatively anaerobic, oxidase negative, and capable of fermenting glucose while typically failing to ferment lactose or sucrose. Hydrogen sulfide production is common in many serovars and assists presumptive identification on selective media [3], [4]. These traits are epidemiologically relevant because they allow the organism to survive in both oxygen-rich and oxygen-limited microenvironments and to colonize the intestinal tract of diverse animal hosts.

Environmental conditions strongly influence persistence and transmission. Temperature, acidity, water activity, organic matter, and competition with other microorganisms determine whether Salmonella grows, remains dormant, or is inactivated. Water activity is particularly important in foods and feed, while prior acid exposure can induce adaptive responses that increase survival during subsequent

refrigeration or acid stress [5]–[8]. Consequently, environmental management cannot be separated from disease control: contaminated drinking water, poorly stored feed, accumulated manure, inadequate refrigeration, and insufficient cleaning can maintain the organism along the farm-to-food continuum.

Water buffalo are economically important for milk, meat, and rural livelihoods, yet they may act as carriers of Salmonella. A study of buffaloes in central Iraq recovered multiple serotypes from fecal and organ samples and demonstrated heterogeneous antimicrobial response patterns [9]. Such findings are relevant to both veterinary productivity and food safety, because infection can reduce animal performance and because slaughter or handling may transfer the pathogen into the human food chain. Earlier burden assessments also identified Salmonella as one of the principal known pathogens contributing to serious foodborne outcomes [10]. This study therefore aims to synthesize the environmental, epidemiological, and antimicrobial evidence relevant to salmonellosis, with particular attention to Iraqi water buffalo.

2. Materials and Methods

This study used a narrative literature-review design combined with descriptive secondary-data synthesis. The evidence base consisted of the sources contained in the original manuscript, bibliographic verification of key journal articles and authoritative public-health materials, and focused selection of publications addressing four domains: Salmonella biology, environmental growth and survival, infection and pathogenesis, and antimicrobial susceptibility in food animals. Priority was given to sources that presented identifiable methods, sample sizes, or numerical findings. Sources with incomplete bibliographic information were not used for quantitative summaries.

Data were extracted into a structured matrix containing the publication, study population, sample source, environmental factor, serotype, prevalence or detection rate, and antimicrobial response. For buffalo-specific analysis, the principal dataset was the Iraqi study that examined 150 milk samples, 150 fecal samples, and 900 post-slaughter organ samples and reported 22 Salmonella isolates [9]. Numerical values were transcribed only when explicitly reported by the source. General microbiological characteristics were cross-checked against diagnostic microbiology texts [3], [4] and environmental evidence on water activity and acid adaptation [5]–[8].

The analysis was descriptive. Percentages were tabulated and visualized without recalculating inferential statistics because individual-level data were unavailable. Organ-specific detection rates and serotype proportions were plotted directly from the published aggregate values. Antimicrobial findings were retained in the reported categories of resistant, intermediate, and susceptible; the review did not reinterpret inhibition zones or apply new breakpoints, although disk-diffusion testing is commonly standardized using the approach described by Bauer et al. [11]. Because the included studies differed in design, period, setting, and laboratory procedures, no meta-analysis was attempted.

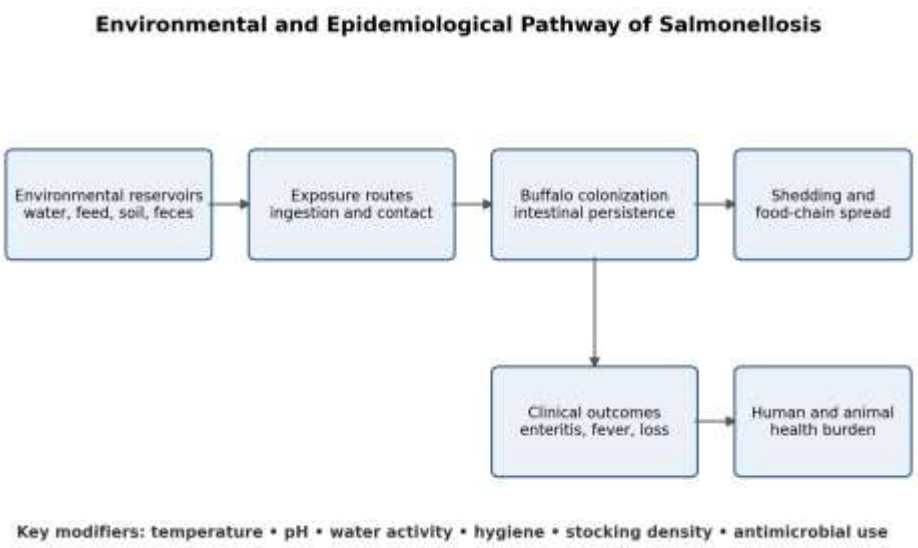

Figure 1. Conceptual relationship between environmental conditions, buffalo infection, shedding, and food-chain transmission.

3. Results and Discussion

3.1 Biological Characteristics and Diagnostic Implications

The reviewed evidence consistently characterizes Salmonella as a Gram-negative, non-spore-forming, facultatively anaerobic bacillus. Most serovars are motile, although host-adapted exceptions such as S. Gallinarum and S. Pullorum are non-motile. The organism generally ferments glucose with acid production, may produce gas and hydrogen sulfide, and usually does not ferment lactose or sucrose [3], [4]. This correction is important because the original manuscript contained a contradictory statement that Salmonella could ferment lactose and sucrose. In practical diagnosis, the combination of colony appearance on selective media, biochemical reactions, antigenic testing, and serotyping is more reliable than any single trait. The Kauffmann–White scheme classifies isolates through somatic, flagellar, and selected capsular antigens, while conventional veterinary bacteriology remains useful for screening and confirmation [12], [13].

3.2 Environmental Growth and Persistence

Temperature, pH, and available water jointly shape Salmonella persistence. Growth is usually most efficient near 35–37 °C, but survival may occur at refrigeration temperatures and under freezing, especially when cells are protected by food matrices or organic matter. The organism tolerates a broad pH range, although neutral conditions are more favorable, and growth becomes progressively restricted as water activity falls. Reference data on sodium chloride solutions demonstrate the central role of water activity in microbial control [5], while broader food-microbiology evidence shows that reduced water availability limits growth without necessarily guaranteeing immediate death [6], [7]. Acid adaptation can also create cross-protection: S. Typhimurium previously exposed to mild acidity showed improved survival during fermented-milk storage [8]. Therefore, isolated control measures are insufficient; refrigeration, drying, acidification, sanitation, and time–temperature control should be used as combined barriers.

Table 1. Environmental Conditions Relevant to Salmonella Growth and Survival

Factor	Favorable/Reported Range	Biological Effect	Control Implication
Temperature	Optimum commonly 35–37 °C	Supports rapid growth under nutrient-rich conditions	Maintain cold chain; avoid prolonged ambient storage

Factor	Favorable/Reported Range	Biological Effect	Control Implication
Low temperature	Survival may continue during refrigeration/freezing	Suppresses growth more than it guarantees elimination	Combine chilling with hygiene and validated processing
pH	Neutral conditions favorable; broad tolerance reported	Acid stress may reduce growth but can induce adaptation	Use validated acidification and avoid sublethal exposure
Water activity	Growth restricted as a_w decreases	Low-moisture matrices can preserve dormant cells	Control humidity and prevent post-process rehydration
Organic matter	Feces, soil, feed, and biofilms provide protection	Reduces effectiveness of cleaning and disinfectants	Remove debris before disinfection and verify sanitation

3.3 Transmission, Pathogenicity, and Host Response

Infection begins when a susceptible host ingests a sufficient dose from contaminated feed, water, food, or the environment. Surviving organisms reach the distal intestine, interact with epithelial cells, and may penetrate the mucosa and multiply in lymphoid tissues. Salmonella virulence is multifactorial and includes adhesion, epithelial invasion, intracellular survival, inflammatory stimulation, and, in some serovars, systemic dissemination [14]. Host age, immune status, dose, stress, and concurrent disease influence clinical severity. Protective immunity involves both cellular and humoral responses, and vaccination can contribute to control where validated products and epidemiological conditions support its use [15]. The frequent absence of obvious signs in carrier animals makes surveillance particularly important, because apparently healthy buffalo can still shed organisms into pens, transport vehicles, slaughter facilities, or milk-handling environments.

3.4 Buffalo Sampling and Serotype Distribution in Iraq

The buffalo-specific Iraqi study provides the most coherent quantitative dataset for this review. It examined 150 lactating buffaloes in the field and collected 150 milk samples; at slaughter, 150 fecal samples and 900 samples from six organ sites were obtained. Twenty-two isolates were recovered from feces and organs, whereas no isolate was obtained from milk [9]. Three serotypes were identified: S. anatum represented 68.18% of isolates, S. Muenchen 18.18%, and S. Enteritidis 13.64%. The predominance of S. anatum indicates that surveillance restricted to the most familiar human-associated serotypes may overlook important animal reservoirs. Nevertheless, the sample was geographically and temporally limited, so the distribution should not be interpreted as a current national profile. Continued serotyping or molecular characterization is needed to determine whether these patterns persist across provinces and production systems.

Table 2. Summary of the Iraqi Buffalo Dataset Used in the Descriptive Synthesis

Component	Number of Samples	Positive Finding	Interpretation
Milk from lactating buffaloes	150	No isolate reported	No evidence of milk positivity in this sample set
Feces at slaughter	150	1.33% positive	Demonstrates potential shedding at slaughter

Component	Number of Samples	Positive Finding	Interpretation
Post-slaughter organs	900 (six sites)	Positive isolates from multiple organs	Supports systemic or carrier-state distribution
Total isolates	22	Three serotypes	S. anatum was dominant (68.18%)

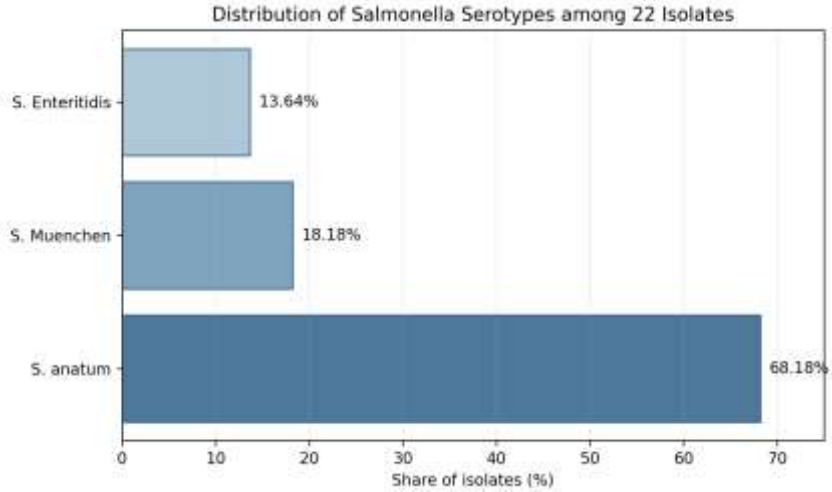

Figure 2. Serotype distribution among 22 Salmonella isolates recovered from buffalo fecal and organ samples.

3.5 Distribution by Sample Source and Clinical Interpretation

Organ-specific results showed the highest reported detection in the bile duct and liver (3.33% each), followed by mesenteric lymph nodes (2.67%), spleen and cecum (2.00% each), and feces (1.33%); milk remained negative [9]. The pattern is biologically plausible because the gallbladder, liver, and lymphatic tissues can harbor organisms during persistent or systemic infection. It also demonstrates why fecal sampling alone may underestimate carriage when intermittent shedding occurs. At the same time, the low percentages should not be read as evidence of negligible risk: even a small number of positive animals can contaminate equipment, carcasses, or shared surfaces during slaughter. The absence of milk isolates in this study is reassuring only for the sampled animals and period; it does not eliminate the need for udder hygiene, pasteurization, and separation of raw and processed dairy products.

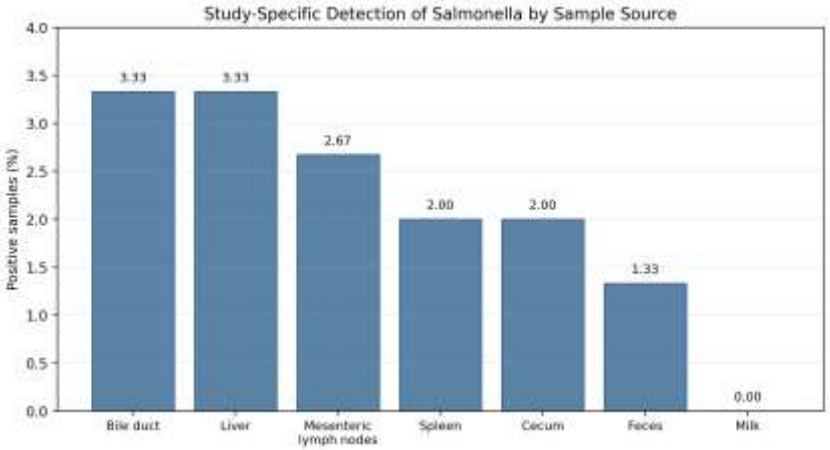

Figure 3. Detection rates by sample source in the Iraqi buffalo study.

3.6 Antimicrobial Susceptibility and Resistance

The antimicrobial profile reported for the 22 buffalo isolates was concerning. All isolates were resistant to chloramphenicol, sulfamethoxazole, erythromycin, cloxacillin, and tetracycline, while all were susceptible to amikacin and trimethoprim; several other agents produced intermediate responses [9]. These findings illustrate the risk of relying on empirical therapy without susceptibility testing. Comparable surveillance in other animal-production settings has documented substantial and changing resistance patterns among Salmonella isolates [16]. Experimental evidence also shows that antimicrobial exposure can select or augment resistant phenotypes [17], while studies in slaughter and retail environments demonstrate how resistant strains may circulate through animal-food systems [18]. An Iraqi slaughtered-cattle study likewise reported complete susceptibility to ciprofloxacin and amikacin but high resistance to cloxacillin, cefixime, and amoxicillin, confirming that response patterns vary by host, study period, and drug-use history [19].

Table 3. Antimicrobial Response Reported for Buffalo Salmonella Isolates

Reported Category	Antimicrobials	Interpretive Note
100% resistant	Chloramphenicol, sulfamethoxazole, erythromycin, cloxacillin, tetracycline	Potential therapeutic limitation; requires stewardship
100% susceptible	Amikacin, trimethoprim	Study-specific result; not a universal treatment recommendation
Intermediate response	Neomycin, gentamicin, cefixime, ciprofloxacin, kanamycin, streptomycin	Highlights the need for isolate-level testing

3.7 Integrated Control, Economic Implications, and Study Limitations

Taken together, the findings support a One Health control strategy. On farms, priority measures include safe water, protected feed storage, manure removal, separation of sick animals, cleaning before disinfection, and routine monitoring of diarrheal or febrile cases. During transport and slaughter, clean equipment, carcass hygiene, prevention of fecal leakage, and separation of clean and dirty zones are essential. In food handling, pasteurization, adequate cooking, hand hygiene, and rapid refrigeration reduce exposure [1], [2]. Antimicrobials should be reserved for clinically justified cases and selected through culture and susceptibility testing. The principal limitations of this review are reliance on heterogeneous secondary sources, the absence of raw datasets, and the age and limited geographic scope of the buffalo evidence. Accordingly, the tables and figures summarize published study results rather than national estimates. Future research should use multicenter sampling, standardized methods, molecular typing, antimicrobial-resistance gene detection, and environmental sampling of water, feed, soil, and slaughter surfaces.

4. Conclusion

Salmonella persists at the intersection of animal health, environmental hygiene, and food safety. Its facultative metabolism, tolerance of varied environmental conditions, ability to colonize the intestinal tract, and capacity for asymptomatic carriage enable continued transmission. The Iraqi buffalo evidence reviewed here confirms recovery of multiple serotypes from fecal and organ samples and shows that internal organs may reveal carriage that is not captured by milk or fecal sampling alone.

Environmental management and antimicrobial stewardship are therefore inseparable components of salmonellosis control. Integrated surveillance, hygienic production and

slaughter, validated food processing, vaccination where appropriate, and susceptibility-guided treatment can reduce animal losses and public-health risk. Broader and more recent Iraqi studies are required before prevalence or resistance patterns can be generalized nationally.

4.1 Recommendations

Buffalo farms and slaughter facilities should implement routine Salmonella surveillance; protect water and feed from fecal contamination; strengthen cleaning, disinfection, and carcass-hygiene procedures; and document antimicrobial use. Veterinary laboratories should report serotype and susceptibility profiles using current standards. Future studies should include several governorates and seasons, compare symptomatic and apparently healthy animals, and integrate culture, molecular confirmation, and environmental sampling.

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