# *Comparative analysis of farming practices and the prevalence of Salmonella enteritidis in broiler chickens from small and large-scale farms within an 80-kilometre radius of Harare*

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## SUMMARY

Non-typical *Salmonella*, particularly *Salmonella enteritidis*, is a major zoonotic pathogen. In Zimbabwe, small-scale poultry farms are a critical part of the food supply chain, yet their disease burden and husbandry practices are not well characterised, leading to public health risks. This study compared the prevalence of *Salmonella enteritidis* and farming practices between small-scale and large-scale broiler farms in the Harare metropolitan region. In a cross-sectional study, 1050 cloacal swabs were collected from 6-week-old broilers across 70 farms (35 small-scale, 35 large-scale) within an 80 km radius of the capital Harare. Samples were cultured and isolates confirmed serologically, with farming practices assessed using a checklist. Prevalence was calculated, and a generalized linear mixed model was used to determine association, accounting for farm-level clustering. The overall prevalence of *Salmonella Enteritidis* was 10.4% (95% CI: 8.6 – 12.2%), with small-scale farms having a significantly higher prevalence (17.7%) than large-scale farms (2.3%). After adjusting for farm-level clustering, broilers from small-scale farms had 18 times higher odds of infection (OR = 18.95% CI: 5.6 – 90.1, p< 0.001). This disparity was strongly associated with markedly inferior biosecurity protocols, limited veterinary supervision, and higher-risk management practices on small-scale farms. Small-scale broiler production systems near Harare are significantly more vulnerable to *Salmonella Enteritidis* contamination due to insufficient biosecurity and management practices. This highlights an immediate necessity for focused interventions, such as farmer education and enhanced support for biosecurity measures, to reduce zoonotic risks and improve food safety.

**Keywords:** *Salmonella Enteritidis*, small-scale farms, large-scale farms, broiler chickens, prevalence, farming practices

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## INTRODUCTION

*Salmonella* is a significant bacterium that causes disease in multiple animal species and humans, posing both socioeconomic and zoonotic concerns. In poultry production, specific serovars like *Salmonella Gallinarum* and *Salmonella Pullorum* cause systemic diseases (e.g., fowl typhoid and pullorum disease), leading to high mortality (Rabsch et al., 2002), while paratyphoid infections by serovars like *Salmonella Enteritidis* result in

subclinical carriage, impaired weight gain, and poor feed conversion ratios. *Salmonella* species are recognized as pathogens of zoonotic importance (Kariuki et al., 2006). Intestines are the primary site of predilection for *Salmonella* species in both humans and poultry. *Salmonella* infection is a cause of human gastroenteritis, and essential sources of human exposure include ingestion of contaminated poultry meat, eggs, and egg products (Rodriguez et al., 1990). Salmonellosis in humans is a consequence of multiple factors, including food, environment, fomites, and animals (Castiglioni-Tessari et al., 2012). The economic impact associated with human salmonellosis arises from the costs of investigations, treatment, prevention of illness, and food production (Torrence & Isaacson, 2003). In the United States, the projected annual medical costs and productivity losses due to Salmonellosis range from $1.188 billion to $11.588 billion (Buzby and Roberts, 2009).

*Salmonella enterica* serotypes are the most common in poultry in many countries. According to Makaya et al. (2012), it constituted 72.8% of *Salmonella* species isolated from poultry in Zimbabwe. It was prevalent in urban and peri-urban areas, including Harare, which recorded a prevalence of 28.7%. This suggests that the public in Harare may be at risk of non-typhoidal Salmonellosis through poultry products. Makaya et al. (2012) also found a higher prevalence of *Salmonella Enteritidis* on large-scale broiler farms compared to small-scale farms in Zimbabwe. However, the opposite would have been expected, considering that most large-scale farms generally have better biosecurity measures than small-scale farms. It is uncertain whether the findings from Makaya et al. (2012) can be directly applied to Harare, as they were based on data collected from nine study sites across the country.

According to the Zimbabwe Poultry Association, small-scale broiler farms make up about 60% of the entire chicken meat supply chain, with the remaining 40% supplied by large-scale producers (Ncube, 2018). However, small-scale poultry farming is often ignored in animal health policymaking because of limited veterinary oversight of their production practices. This may imply that biosecurity and disease control measures are weaker in small-scale poultry farms, which could result in outbreaks of animal and zoonotic diseases such as salmonellosis in Harare. Most large-scale farms benefit from veterinary supervision because many are contracted by private companies owning large chicken slaughterhouses. These contract farms are audited by State veterinarians and by the contracting companies to enhance productivity and disease management. The State veterinarians also inspect hatcheries, breeder farms, and large-scale broiler farms, focusing on farm biosecurity and the *Salmonella* control system. Some large-scale poultry producers in Zimbabwe vaccinate their breeder flocks against salmonellosis. The import conditions for broiler-hatching eggs mandate that both the eggs and the parent stock be tested and confirmed free of *Salmonella* before entry into Zimbabwe.

Recent studies have shown that the transmission of *Salmonella* to offspring is significantly influenced by parental flock management. Research on Iran and China confirms that vertical gearbox paths remain primary in broiler production systems worldwide (Piryaei et al., 2025; Shen et al., 2023). Multidrug-resistant strains, including *Salmonella* Kentucky ST198, have emerged in both poultry and clinical settings in Zimbabwe (Mashe et al., 2023), indicating a shift in epidemiological hazards that warrants revised surveillance. Recent isolates from Zimbabweans show concerning resistance to erythromycin (100%), ampicillin (96%), and tetracycline (88%), consistent with African studies where 78% of poultry *Salmonella* show multidrug resistance (Ramtahal et al., 2022). This corresponds with Iranian broiler data showing 92% ampicillin resistance (Piryaei et al., 2025), implying extensive empirical antibiotic use in small-scale systems.

According to Karenga (1997) and Matope et al. (1998), there has been an increase in *Salmonella Enteritidis* prevalence in both large-scale and small-scale chicken farms in Zimbabwe, which was confirmed by Makaya et al (2012). This comparative cross-sectional investigation aimed to investigate various farming practices and the frequency of *Salmonella Enteritidis* in broiler chickens from large-scale and small-scale farms within an 80-kilometre radius of Harare, Zimbabwe. This included evaluating management strategies and biosecurity policies for their efficacy in reducing infection rates and related transmission concerns. By investigating the association between farming practices and *Salmonella Enteritidis* prevalence, the study aimed to provide practical insights that enhance safe broiler production systems and, ultimately, the health of consumers.

## MATERIALS AND METHODS

A cross-sectional study was conducted between February and December 2024 to compare farming practices and the prevalence of *Salmonella Enteritidis* in broiler chickens from selected small-scale and large-scale farms. For this study, a farm with a flock of ≥ 10,000 broiler chickens was considered a large-scale farm, and a farm with a flock of < 10,000 was considered a small-scale farm, as done in a study by Makaya et al. (2012). The target population for this study consisted of broiler chickens on farms located within an 80 km radius of Harare.

### Selection of sampling sites and birds

A two-stage stratified random sampling approach was employed. First, a sampling frame of all registered broiler farms within an 80 km radius of Harare was obtained from the Department of Veterinary Technical Services. The season was based on the month of sample collection, with the rainy season spanning from November to April and the dry season from May to October (Vayeni, 2014). Farms were stratified into two categories, i.e., small-scale (flock size < 10000) and large-scale (flock size ≥ 10000). From each stratum, 35 farms were selected using a computer-generated random sample number sequence to ensure a representative and unbiased sample.

The sample size was calculated using STATULATOR for comparing two independent proportions, accounting for an expected prevalence of 10% in large-scale farms and 20% in small-scale farms, based on prior data from Makaya et al. (2012). The calculation assumed a power of 80%, a confidence level of 95%, and a design effect to adjust for clustering. A design effect of 2.75 was applied, calculated from an anticipated intra-class correlation coefficient (ICC) of 0.1 and a cluster (farm) size of 15 birds. This yielded a total required sample size of 1050 birds (525 per stratum), distributed across 70 farms (35 per stratum).

On each selected farm, fifteen 6-week-old broiler birds were randomly sampled from a single house. Randomisation at the bird level was achieved by dividing the house into sections, randomly selecting a starting point, and systematically sampling every k-th bird (where k = total flock size in the house / 15) to ensure even coverage. We acknowledge that collecting a fixed number of samples (n = 15) from each farm, regardless of its total flock size, is a limitation. This approach does not account for potential variations in exposure risk correlated with population size and may affect the precision of farm-level prevalence estimates. However, this method was chosen for logistical consistency and to meet the requirements of the cluster-adjusted sample size calculation.

### Sampling, culture, and identification

Cloacal swabs were aseptically collected using sterile, dry cotton-tipped swabs (Puritan Medical Products, Guilford, USA). A sterile swab was inserted approximately 1-3 centimetres into the cloaca, pressed against the walls of the cloaca for less than a minute, and subsequently placed in a bottle containing 10 mL Rappaport-Vassiliadis broth (Oxoid, UK), a *Salmonella*-enrichment broth. The bottles were transported in a cool box at approximately 4°C to the Department of Livestock and Veterinary, Central Veterinary Laboratory in Zimbabwe, in Zimbabwe within 24 h of collection.

For each cluster (farm) size of 15 birds, the following details were recorded on the field record sheet: Date of collection, Name of the farm of origin, Small-scale or Large-scale farm and a list of 15 chicken identification numbers. The samples were incubated at 37°C for 24 h. After enrichment, a loopful was sub-cultured onto XLD (Xylose Lysine Deoxycholate) agar (Oxoid, UK) in petri dishes and incubated for another 24 hours at 37°C. After examination, plates yielding pink or red colonies with a black centre were classified as suspect. These colonies underwent urease activity testing on urea agar to distinguish between Proteus and Salmonella species, incubated at 37°C for 24 hours. Urease-negative colonies were transferred to Triple Sugar Iron (TSI) agar (Oxoid, UK) along with mannitol, glucose, lactose, and sucrose for further testing, all incubated for an additional 24 hours. Suspect TSI colonies exhibited red slants with black centres and yellow butts. Additional biochemical tests included indole (negative for suspect *Salmonella*), oxidase (negative per manufacturer's instructions), and lysine

decarboxylase (positive). Confirmation of *Salmonella Enteritidis* was achieved through serotyping of positive biochemical test results. Pure and fresh cultures were maintained through nonselective media such as Blood agar and Nutrient agar. These suspect colonies were then serotyped using polyvalent O and H commercial antiserum to help in the confirmation of the *Salmonella* colonies. Confirmation of *Salmonella Enteritidis* was done according to the description presented in **Tables 1** and **2**.

**Table 1**. *Salmonella* polyvalent O and H antiserum

| Polyspecific antiserum | Result | Conclusion/Action |
|---|---|---|
| Poly O: A-S | No agglutination -Negative | Not *Salmonella* spp. |
| | Agglutination Positive | Use Poly H antisera |
| Poly H: Phase 1 and 2 | No agglutination-Negative | *Salmonella* Pullorum / Gallinarum – confirm with biochemical tests |
| | Agglutination- Positive | Use monospecific O and H antisera to differentiate *Salmonella* of veterinary importance. |

**Table 2**. Differentiation of *Salmonella* Species of Veterinary Importance

| Salmonella species | Somatic (O) Antigen | Flagella (H) Antigens | |
|---|---|---|---|
| | | Phase 1 | Phase 2 |
| *S. Enteritidis* | 1, 9, 12 | g, m | 1, 7 |
| *S. typhiumurium* | 1, 4 [5], 12 | i | 1, 2 |
| *S. gallinarum* | 1, 9, 12 | Nil | Nil |
| *S. pullorum* | 9, 12 | Nil | Nil |
| *S. paratyphi* | 1, 2, 12 | a | 1,5 |
| *S.choleraesuis* | 6, 7 | c | 1,5 |

**Compilation of biosecurity and management practices**

Data on biosecurity and management practices were collected through direct observation and farmer interviews using a structured checklist (Supplementary Data S1). The checklist was designed based on established guidelines from the Food and Agriculture Organisation (FAO) and previous literature. It assessed key parameters across several domains:

- **Farm Infrastructure**: Presence of a perimeter fence, signage restricting entry, and vehicle disinfection facilities (type: wheel dip or full spray).
- **Animal Management**: Cohabitation or access of other livestock (cattle, goats) and domestic animals (dogs, cats) or other bird species to the broiler houses.
- **Operational Biosecurity**: Use of farm-specific personal protective equipment (PPE), including clothing and footwear for workers and visitors, availability and use of handwashing stations with soap, and presence of functional footbaths with disinfectants.
- **Pest Control**: Implementation of rodent and fly control programs.
- **Husbandry Practices**: Water source (borehole or well) and water treatment practices, litter management, and downtime between production cycles.

In this study, biosecurity and management practices across multiple farms were meticulously observed and documented using a detailed checklist. The collected data were subsequently entered into an Excel spreadsheet for analysis. The analysis involved calculating the frequencies and percentages for each observed parameter. For the statistical assessment of each parameter, the proportional test was employed utilising R software (version 4.3.1; https://www.r-project.org/), ensuring interpretations were based on results obtained at a 95% confidence level.

**Data management and analysis**

Data on the field record sheet were entered into Microsoft Excel (version 2013), and additional variables for Month and Season were created. Descriptive analysis of the dataset was performed

using IBM SPSS Statistics version 22. Descriptive analysis was performed using frequency distributions for each variable and contingency tables for each variable based on *Salmonella Enteritidis* results. The calculation of true prevalence was performed using the formula to estimate true prevalence from apparent prevalence, as described by Dohoo et al. (2009). The 95% Confidence intervals of both Apparent and True Prevalence were calculated using the formula: P-1, 96 x √ [P (1-p)]/n to P + 1, 96 x √ [P (1-p)]/n. Univariate logistic regression and calculation of the Intra-class correlation coefficient (ICC) were performed using. Generalised Linear Mixed Model in GenStat version 17.1.0.14713 64-bit edition (VSN International, 2014). Clustering was deemed high for random effects with an ICC > 0.3 (Dohoo et al., 2009). Data for farming practices were analysed for each parameter using the proportional test in R software (version 4.3.1; R Foundation for Statistical Computing, https://www.r-project.org/) at a 95% confidence level.

## RESULTS

### Distribution of *Salmonella Enteritidis* according to samples collected

Of the 70 farms sampled, 35 were small-scale and 35 were large-scale farms. Among the small-scale farms, 18 out of the 35 (51.4%) sampled farms had at least one broiler chicken positive for Salmonella Enteritidis, with two farms having all 15 samples test positive (**Figure 1**). Among large-scale farms, 5 out of 35 (14.3%) farms had at least one positive sample, with the highest number of positive samples for a single farm being 4 out of 15 samples. Among the samples from small-scale farms, 93 out of 525 (17.7%) were positive for *Salmonella Enteritidis*. For samples from large-scale farms, 12 out of 525 (2.3%) were positive for *Salmonella Enteritidis* (**Figure 1**). In total, 105 out of 1050 (10%) samples were positive for *Salmonella Enteritidis*. The unadjusted odds of *Salmonella Enteritidis* infection in chickens from small-scale farms were 9.2 times higher than the odds of *Salmonella Enteritidis* infection in those from large-scale farms.

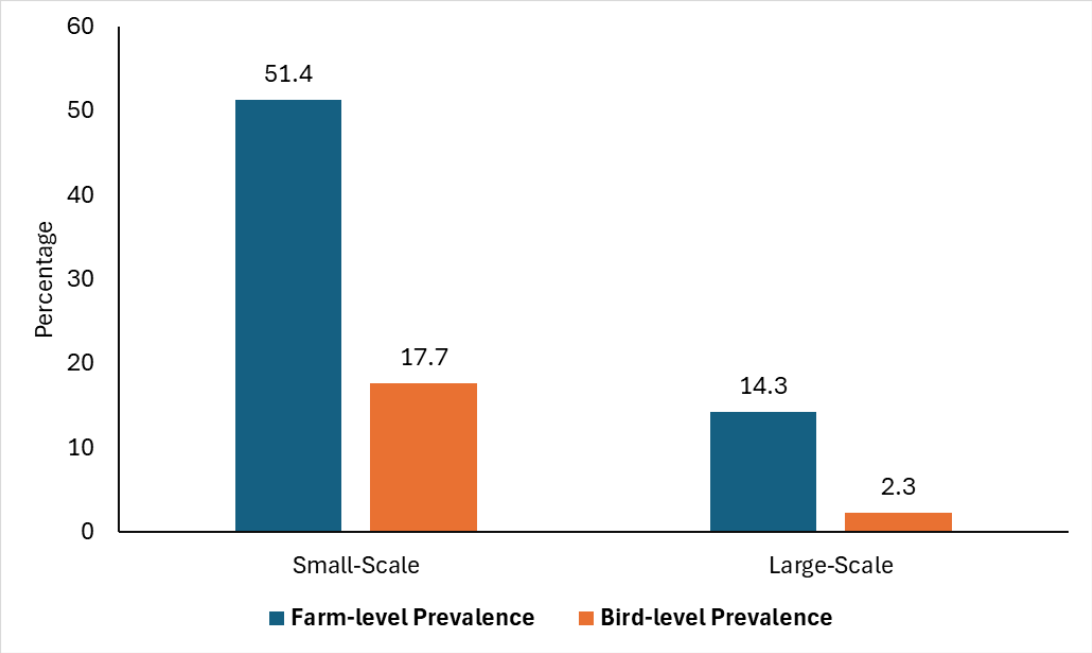


**Figure 1**. *Salmonella Enteritidis* farm-level prevalence and sample-level prevalence.

### The apparent and actual prevalence of *Salmonella Enteritidis* in the samples collected

Out of the total 1050 cloacal swab samples collected, 105 were positive for *Salmonella Enteritidis*. The overall apparent prevalence of *Salmonella Enteritidis*, along with its 95% confidence interval (CI), was 10.0% (lower limit, 8.2%; upper limit, 11.8%), while the overall true prevalence of *Salmonella Enteritidis* was 10.4% (lower limit, 8.6%; upper limit, 12.2%). The true prevalence was calculated using a sensitivity and specificity of 98% for laboratory tests used in

detecting *Salmonella Enteritidis* in the cloacal swabs submitted for testing.

**Distribution of *Salmonella Enteritidis* according to season and month of the year.**

In the dry season, 690 out of 1050 samples (65.7%) were collected, with 63 (9.1%) being positive for *Salmonella Enteritidis*. In the rainy season, 360 out of 1050 samples (34.3%) were collected, with 42 (11.7%) being positive for *Salmonella Enteritidis*. The unadjusted odds of *Salmonella Enteritidis* in chickens sampled in the rainy season were 1.3 (95% CI 0.87-1.99) times the odds of *Salmonella Enteritidis* in those sampled in the dry season. As the 95% confidence interval included the null value of one, this indicates that there is no statistically significant association between *Salmonella Enteritidis* in chickens and the season of the year. During August, the collection efforts yielded the largest number of samples, with 270 out of the total 1,050 samples (25.7%) obtained during this period. Despite this substantial sampling, only 1 out of the 270 samples (0.4%) tested positive for *Salmonella Enteritidis*. This low positivity rate highlights a notable contrast between the volume of samples collected and the actual detection of *Salmonella Enteritidis* in August. The lowest number of samples collected in a month was 75 (7.1%), and this number was collected in April, May, and June, with 1 (1.3%), 4 (5.3%), and 15 (20%) being positive for *Salmonella Enteritidis*, respectively (**Figure 2**).

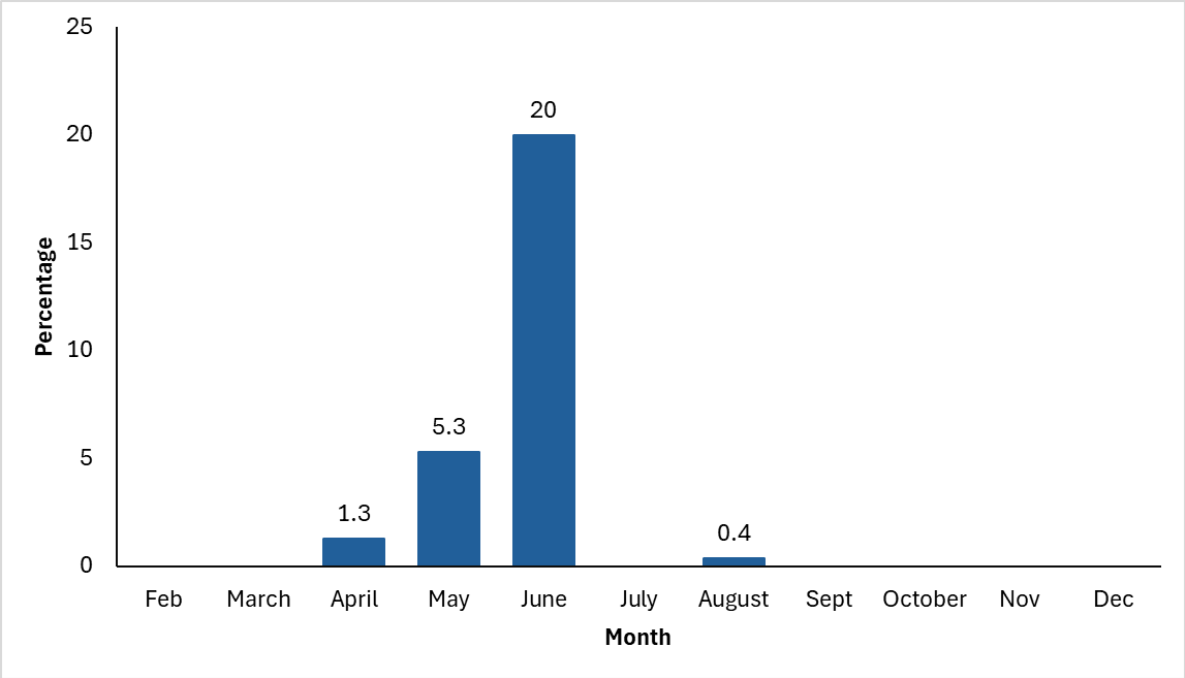


**Figure 2**. Distribution of *Salmonella Enteritidis* according to the month of the year.

**Consideration of the intra-class correlation coefficient (ICC)**

An ICC of 0.88 was calculated for the farm for the *Salmonella Enteritidis* results. This implies that the data is highly clustered at the farm level, which is also explained by the fact that 15 chicken samples were collected from each farm.

**Univariate regression analyses for the association between *Salmonella Enteritidis* and possible risk factors**

Univariate analysis after adjusting for the random effect for farm, broiler chickens from small-scale farms were 18 (95% CI 5.6- 90.1) times more likely to be infected with *Salmonella Enteritidis* compared to chickens from large-scale farms, with a likelihood chi-squared test p-value < 0.001. Broiler chickens sampled during the rainy season were 2.2 (95% CI 0.6-8.4) times more likely to be infected with *Salmonella Enteritidis* compared to

those sampled in the dry season, with a likelihood chi-squared test p-value of 0.24.

**Comparison of farming practices on small and large-scale farms**

Systematic assessment revealed profound and statistically significant deficits in biosecurity across small-scale broiler operations to large-scale facilities (**Table 3**; all comparisons $p < 0.05$). fundamental structural controls were frequently absent in small-scale systems: perimeter fencing was present in only 43% of small-scale farms compared to 100% of large-scale farms ($p < 0.001$). furthermore, practices with high zoonotic risk, such as housing other animal species (83% of small-scale vs. 0% of large-scale; $p < 0.001$) and permitting wild bird access to broiler houses (77% of small-scale vs. 0% of large-scale), were exclusively observed in small-scale operations.

Critical operational biosecurity measures were similarly lacking in small-scale farms. No small-scale farms employed vehicle disinfection, whereas large-scale farms (100%) had such facilities ($p < 0.001$). the use of dedicated personal protective equipment was rare on small-scale farms (3% vs. 100% for large-scale farms), and access to handwashing stations with soaps (3% of small-scale vs. 100% of large-scale farms; $p < 0.001$) and functional footbaths (23% of small-scale vs. 100% of large-scale farms) was severely limited.

Pest control and environmental management were significantly less robust within various farming systems. Rodent control programs were implemented on 51% of small-scale farms versus 100% of large-scale farms. Similarly, fly control was observed on 54% of small-scale farms compared to 100% on large-scale farms. Adequate ventilation, defined by the presence of functional windows, vents, or fans, was present in 49% of small-scale farms and 100% of large-scale farms.

Water sourcing and safety also differed significantly, with all large-scale farms (100%) providing treated borehole water to their broilers. In contrast, 83% of small-scale farms relied on well water, with none reporting the use of water treatment or pathogen quality testing ($p < 0.001$ for both source and treatment comparisons).

**Table 3**. Summary of the farming practices observed at small and large-scale broiler chicken farms.

| Parameters | Small scale count (%) | Large scale count (%) | $X^2$ | p-value |
|---|---|---|---|---|
| **Keeping other animals** | | | | |
| No | 6 (17) | 35 (100) | 138.48 | 2.2e-16 |
| Yes | 29 (83) | 0 (0) | | |
| **Other birds have access to broilers.** | | | | |
| No | 8 (23) | 35 (100) | 121.97 | 2.2e-16 |
| Yes | 27 (77) | 0 (0) | | |
| **Farms have an outer demarcation.** | | | | |
| yes | 15 (43) | 35 (100) | 76.948 | 2.2e-16 |
| No | 20 (57) | 0 (0) | | |
| **Vehicle disinfection facility availability** | | | | |
| yes | 0 (0) | 35 (100) | 196.2 | 2.2e-16 |
| No | 35 (100 | 0 (0) | | |
| Type of disinfection facility available | | | | |
| hand spray | 0 (0) | 0 (0) | | |
| wheel dipping | 0 (0) | 25 (71) | 107 | 2.2e-16 |
| Vehicle spraying | 0 (0) | 10 (29) | | |
| **Restricted Entry sign** | | | | |
| No | 33 (94) | 0 (0) | 173.6 | 2.2e-16 |
| Yes | 2 (6) | 35 (100) | | |
| **Specific clothing** | | | | |
| No | 34 (97) | 0 (0) | 184.49 | 2.2e-16 |
| Yes | 1 (3) | 35 (100) | | |
| **Specific shoes** | | | | |
| No | 34 (97) | 0 (0) | 184.49 | 2.2e-16 |
| Yes | 1 (3) | 35 (100) | | |
| **Change clothes/shoes before and after** | | | | |
| No | 34 (97) | 0 (0) | 184.49 | 2.2e-16 |
| Yes | 1 (3) | 35 (100) | | |
| **Visitors clothing** | | | | |
| No | 35 (100) | 0 (0) | 196.2 | 2.2e-16 |
| Yes | 0 (0) | 35 (100) | | |
| **Handwashing station** | | | | |
| no | 34 (94) | 0 (0) | 184.49 | 2.2e-16 |
| Yes | 1 (3) | 35 (100) | | |
| **Soap present** | | | | |
| No | 35 (100) | 0 (0) | 196.2 | 2.2e-16 |
| Yes | 0 (0) | 35 (100) | | |
| **Foot bath** | | | | |
| No | 27 (77) | 0 (0) | 74.42 | 2.2e-16 |
| Yes | 8 (23) | 35 (100) | | |
| **Rodent control** | | | | |
| No | 17 (49 | 0 (0) | | |
| Yes | 18 (51) | 35 (100) | 62.279 | 2.981e-15 |
| **Fly control** | | | | |
| Yes | 19 (54) | 35 (100) | 57.171 | 3.995e-14 |
| No | 16 (46) | 0 (0) | | |
| **Source your drinking water for the birds** | | | | |
| Borehole | 6 | 35 | 138.48 | 2.2e-16 |
| Well | 29 | 0 | | |

## DISCUSSION

Our study showed a significantly higher prevalence of Salmonella *Enteritidis* in broiler chickens from small-scale farms compared to large-scale operations within the Harare metropolitan region. This disparity is strongly associated with systemic deficiencies in biosecurity infrastructure and management practices observed in small-scale systems, including inadequate access control, cohabitation with other species, and poor protocols. The overall *Salmonella Enteritidis* prevalence of 10.4% in our study is lower than the 20.7% reported by Makaya et al. (2012). This apparent reduction may not signify a true decrease in burden but likely reflects key methodological differences. Our study employed a larger, randomised sample frame (N = 1050 vs. N = 270) focusing specifically on the Harare metropolitan region, whereas the earlier study pooled samples from nine sites across Zimbabwe, which may have included areas of higher endemicity (Makaya et al., 2012). Furthermore, differences in culture protocols and sampling timing could influence prevalence estimates. Therefore, the figures are not directly comparable, and our data provides a more robust, geographically specific baseline for the Harare metropolitan region.

The markedly higher prevalence in small-scale farms aligns with continental analysis identifying biosecurity gaps as the primary risk factor for Salmonella in African poultry systems (Ramtahal et al., 2022). Our data corroborates this, showing that small-scale farms consistently lack basic measures such as perimeter fencing, vehicle disinfection, and personnel hygiene facilities. The common practice of keeping multiple species and allowing wild birds access creates frequent opportunities for pathogen introduction, a risk which is amplified by the near absence of veterinary oversight. These findings are consistent with global studies where non-commercial flocks with limited to no biosecurity exhibit higher pathogen loads (Punchihewage-Don et al., 2023).

The role of antimicrobial resistance (AMR) adds a vital layer of public health urgency to our findings. Although our study did not test for AMR, the biosecurity failures we documented are well-known drivers of routine, non-therapeutic antimicrobial use in small-scale systems (Gufe et al., 2023). This practice creates selective pressure for the emergence and spread of resistant pathogens. In Zimbabwe, this is exemplified by the recovery of highly resistant clones like Salmonella Kentucky ST198 from both poultry and clinical settings (Mashe et al., 2023). Therefore, the high-prevalence, low biosecurity environment we describe in small-scale farms presents a potential hotspot for the amplification of such multidrug-resistant strains.

To reduce these risks, a multifaceted approach is essential. First, empowering small-scale farmers through targeted education on cost-effective biosecurity and hygiene is vital. Second, exploring alternatives to antibiotics, such as probiotics, bacteriophages, and phytogenic feed additives, could help manage Salmonella loads without contributing to AMR (He et al., 2024; Thanki et al., 2023). Regarding meat inspection, moving beyond macroscopic examination to include microbiological testing is a recognised strategy for improving food safety. This approach is central to the risk-based meat inspection system advocated by the European Food Safety Authority for Poultry, specifically to control biological hazards like Salmonella that are not detectable by visual inspection alone (EFSA, 2012).

Our study has limitations. The fixed sampling of 15 birds per farm does not consider flock size-dependent exposure risks, which could affect the accuracy of farm-level prevalence estimates. Additionally, we did not trace the source of chicks or parent flocks, which are potential points of vertical transmission (Castiglioni-Tessari et al., 2012; Hamilton, 2016). Future longitudinal studies involving genetic typing of isolates and AMR profiling would clarify transmission dynamics and resistance pathways. In conclusion, the high prevalence of Salmonella Enteritidis in small-scale broiler farms around Harare results from inadequate biosecurity. This presents a significant zoonotic threat, worsened by the broader issue of antimicrobial resistance. Addressing this problem requires policy interventions that support small-scale farmers in adopting feasible biosecurity measures, along with enhanced surveillance

systems that monitor not only pathogen prevalence but also emerging resistance patterns.

## CONCLUSION

The data indicated significant disparities in farming practices and the prevalence of *Salmonella Enteritidis*. The study revealed that small-scale farms use less stringent biosecurity precautions than large-scale enterprises. Inadequate sanitation methods and insufficient access control may have contributed to an increased risk of contamination. Large-scale farms tend to use standardised procedures, such as regular health checks and improved feed and water management, which are essential for lowering bacterial prevalence. *Salmonella Enteritidis* was much more prevalent in samples from small-scale farms. This indicates that farming methods are directly linked to the risk of infection. Large-scale farms, on the other hand, exhibited lower levels of contamination, likely due to stricter health management measures. These findings underscore the importance of implementing effective biosecurity and management practices on small-scale farms to mitigate the risk of *Salmonella Enteritidis* infection. Educational initiatives that focus on best practices in poultry health management may improve safety and minimise public health hazards connected with chicken products. Furthermore, locally practicable therapies, such as phased vaccine deployment or antimicrobially tested ethnoveterinary botanicals, may help address resource shortages. Continental frameworks highlight the policy changes that must be addressed by focusing on small-scale value chains, including subsidised diagnostics and AMR stewardship initiatives.


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## STATEMENT OF ANIMAL RIGHTS

The animal rights we observed since the birds used for the study were already stunned and bled during slaughter, and the owners of the slaughterhouses and farms were aware of the study.

## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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