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RESEARCH ARTICLE

Salmonella in Malaysia: Outbreaks, contamination sources, serovar distribution and antimicrobial resistance patterns

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ABSTRACT

Salmonella is one of the leading causes of foodborne illnesses worldwide, with the ability to contaminate a wide range of sources. The identification of the frequently contaminated sources is vital for improving the management of *Salmonella* infections and outbreaks. As there is growing concern on bacterial resistance to antimicrobial agents globally, it is crucial to monitor the resistance of *Salmonella* to antimicrobial agents for effective treatment of salmonellosis and prudent use of antibiotics. The epidemiology of *Salmonella,* including outbreak patterns, serovars prevalence and antimicrobial resistance profiles, could differ by region. Therefore, assessing the local status of *Salmonella* is crucial for implementing targeted interventions. This review provides an overview of foodborne disease and *Salmonella*-related outbreaks in Malaysia, focusing on *Salmonella*'s sources of isolation, serovars and antimicrobial resistance patterns. In Malaysia, food poisoning outbreaks remain a recurring public health issue, and *Salmonella* is one of the main causative agents with fatal cases. However, the true burden of salmonellosis is difficult to determine as data on non-typhoidal salmonellosis are lacking. *Salmonella* was detected in both human and non-human samples, with *S.* Typhimurium and *S.* Enteritidis being the most common serovars. *Salmonella* isolates in Malaysia exhibited a wide range of antimicrobial susceptibility patterns, with notably high resistance to erythromycin and penicillin. The review highlights the need for continuous surveillance of *Salmonella* infections, encompassing both typhoidal and non-typhoidal salmonellosis, as well as systematic monitoring of contamination sources and antimicrobial resistance patterns to improve understanding and ensure effective management of salmonellosis in Malaysia.

Keywords: *Salmonella*; salmonellosis; outbreaks; serovars; antimicrobial resistance.

INTRODUCTION

Foodborne diseases are a significant global public health concern. Approximately 600 million people have become sick and 420,000 die each year due to foodborne illnesses (WHO, 2024). Foodborne diseases are caused by a range of agents, including microorganisms (bacteria, viruses, parasites) and chemicals. Among these, bacteria are the primary agents which account for more than half (59.8%) of all foodborne illness cases (WHO, 2024). Among bacterial pathogens, *Escherichia coli* (*E. coli*) is the leading cause of foodborne illness (30.9%), followed by *Campylobacter* (26.57%) and *Salmonella* (24.5%). More than half (65.1%) of deaths due to foodborne diseases were also caused by bacteria (65.1%), of which *Salmonella* contributed to the highest number of deaths (45.38%).

Salmonellosis, the disease caused by *Salmonella,* is a common cause of foodborne illness, particularly in the United States and European Countries (ECDC, 2022). *Salmonella* outbreaks are frequently reported throughout the world, with over 60% occurring in European countries (Popa & Papa, 2021). According to the recent report published by the European Centre for Disease Prevention and Control (ECDC, 2025), more than 500 people have been diagnosed with salmonellosis in nine European countries between January 2023 to January 2025. The recurring outbreaks highlight the urgent need for effective mitigation strategies. Similarly, *Salmonella* outbreaks are a persistent issue in Southeast Asia, with foodborne illnesses caused by contaminated food continuing to pose a significant public health concern.

The bacterium *Salmonella* belongs to the family *Enterobacteriaceae*. Currently, *Salmonella* is classified into two main species: *S. enterica* and *S. bongori,* with over 2,500 identified serovars (Williams *et al*., 2025). *S. enterica* is further divided into six subspecies: *S. enterica enterica* (I), *S. enterica salamae* (II), *S. enterica arizonae* (IIIa), *S. enterica diarizonae* (IIIb), *S. enterica houtenae* (IV), and *S. enterica indica* (VI). Interestingly, among these subspecies, *S. enterica* subspecies *enterica* (subsp. I) is the principal cause of human salmonellosis and is further grouped into two clinical forms: typhoidal and non-typhoidal salmonellosis. Typhoidal salmonellosis is caused by *S.* Typhi and *S.* Paratyphi A, B and C. Both *S.* Typhi and *S.* Paratyphi are highly host-specific, and restricted to humans, while *S.* Paratyphi B and C can cause illness in animals, primarily the higher primates. The non-typhoidal salmonellosis is caused by other *Salmonella* serovars that can infect a wide range

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of hosts, including humans and animals (Lamichhane *et al*., 2024). Globally, among the salmonellosis cases, non-typhoidal *Salmonella* (NTS) is responsible for a large number of cases (89.4%) compared to typhoidal *Salmonella* (10.6%) (WHO, 2024). However, typhoidal *Salmonella* caused a higher number of deaths (52.2%) compared to NTS (47.8%).

The transmission of *Salmonella* to a healthy individual primarily occurs through the direct consumption of contaminated food. However, indirect contact with the contaminated environmental surfaces and infected animals also contributes to the occurrence of salmonellosis in humans. *Salmonella* is commonly found in animal-derived products such as meats, dairy, and eggs (Vidayanti *et al*., 2021). *Salmonella* contamination has also been reported in fresh produce, including vegetables and fruits (Huoy *et al*., 2024). In addition, *Salmonella* was also detected in poultry farm environments (Kumar *et al*., 2025). The ability of *Salmonella* to survive in diverse environments, including food, water, and various surfaces, greatly contributes to its widespread distribution and its potential to cause infection in both humans and animals.

Antibiotic treatment for salmonellosis is available; however, the development of antibiotic resistance in *Salmonella* isolates complicates the treatment regimen of this disease. The emergence of multidrug-resistant (MDR) strains further contributes to the challenge in effective treatment and increases the severity of the disease. A recent study reported that S. *enterica* serotypes were observed to have a decreasing susceptibility to azithromycin (Sivanandy *et al*., 2025), one of the four antibiotics (azithromycin, ceftriaxone, ciprofloxacin, amoxicillin) commonly used in salmonellosis treatment. Severe drug-resistant typhoid cases, involving *S. enterica* serovar Typhi, *S*. Paratyphi A and B, were reported in Pakistan since 2016, and the situation is worsening over the years (Fasih *et al*., 2023). Highly resistant patterns were also observed in *Salmonella* isolates against fluoroquinolones and third-generation cephalosporin, where these two antibiotics are the primary-line agents used to treat typhoid fever (Fatima *et al*., 2021).

Salmonella is one of the main causative agents of foodborne disease in Malaysia. However, data on the actual number of salmonellosis cases in the country remain limited. Given the increasing global concern on salmonellosis due to its high mortality rate and frequent outbreaks, it is important to determine the exact number of cases, the antimicrobial resistance patterns, and sources of infection within specific geographic regions. Such information is crucial for developing and implementing targeted interventions to prevent foodborne illnesses and reduce mortality. Hence, this review aims to provide an overview of foodborne disease and outbreaks in Malaysia, with special emphasis on *Salmonella*'s sources of contamination, serovars and antimicrobial susceptibility patterns.

METHODS

Foodborne outbreaks

The information on foodborne disease outbreaks in Malaysia was retrieved through an internet search using the keywords "Foodborne", "Outbreak", "Malaysia" and "*Salmonella*", restricted to articles published in English. Screenshots of media articles are provided in Supplementary Figure 1.

Antimicrobial susceptibility patterns

For studies on the detection and antimicrobial susceptibility testing of *Salmonella*, the PubMed, Web of Science (WOS), and Scopus databases were searched using the terms "Detection", "Isolation", "*Salmonella*", "Antimicrobial Susceptibility Testing", "Malaysia" and "Resistance" with no restriction on language or publication date. A total of 317 articles (PudMed=80, WOS=167, Scopus = 70) were retrieved. Articles conducted in other countries, duplicate records across databases, and inaccessible articles were excluded, resulting in 47 open-access articles eligible for review. Of these, 39 articles included antimicrobial susceptibility testing.

Sources of other data

Additional sources, including non-indexed local journals, clinical cases reports, bulletins, newspapers, and data from the Ministry of Health Malaysia, were also incorporated in the results and discussion sections. Relevant articles from the reference lists of retrieved publications which were not captured during the preliminary results were also included in this review. Screenshots of media articles are provided in Supplementary Figure 1.

Ethical requirements

Ethical approval was not required in this review, as it was based entirely on previously published literature and anonymised data.

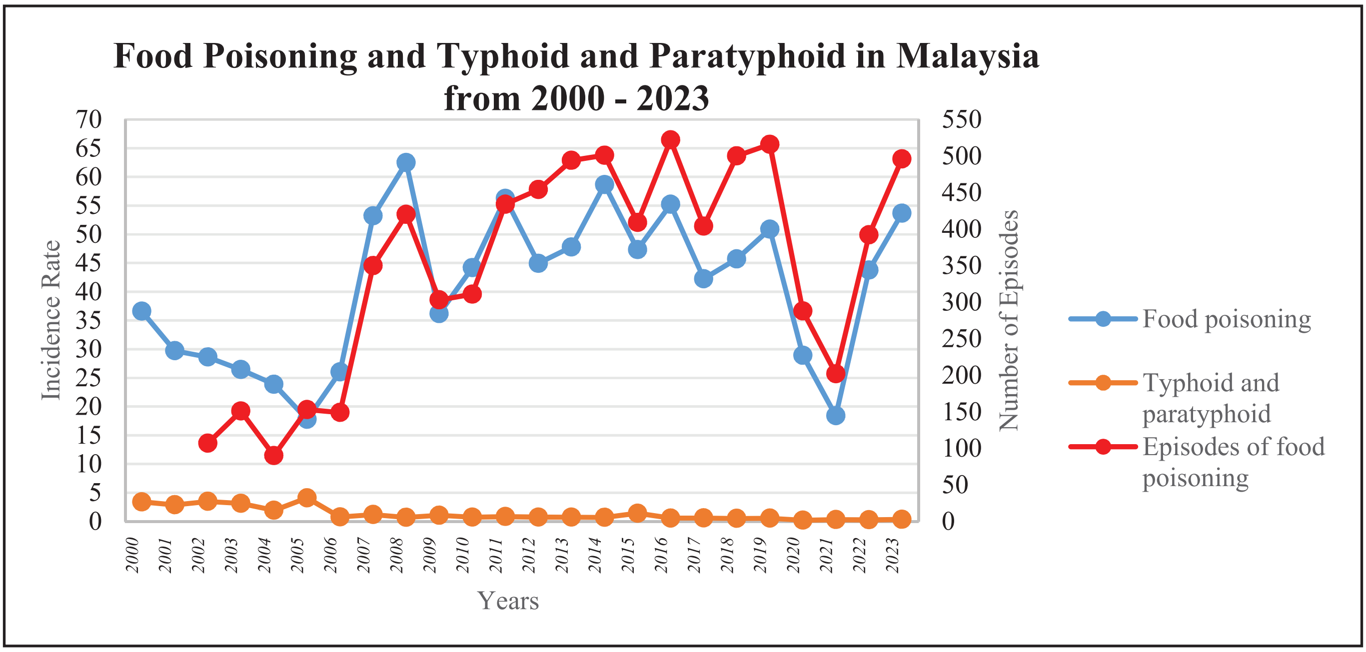

Figure 1. Number of episodes and incidence rate of food poisoning and typhoid and paratyphoid in Malaysia from 2000 – 2023.

RESULTS

Foodborne diseases in Malaysia

Foodborne disease or commonly known as food poisoning, is defined as an acute onset of vomiting, diarrhea and other acute symptoms, including neurological symptoms associated with ingestion of food and drinks (WHO, 2024; MOH, 2017a). The illness could be caused by either one of the following: pathogens (bacteria, viruses, parasites), prions or chemicals. In Malaysia, the burden of foodborne diseases is monitored through the actual number of cases and the number of episodes. An episode of food poisoning outbreak is described as two or more people experiencing illness associated with the consumption of a common food or meal, with epidemiological linkage to time, place, or person (MOH, 2017a). Over the past 23 years, the number of episodes and incidence rate of food poisoning have fluctuated in Malaysia (Figure 1) (MOH, 2000 – 2005; MOH, 2006a, b; MOH, 2008 – 2016; MOH, 2017a, b; MOH, 2018a – 2023a; MOH, 2018b – 2023b). The highest number of episodes (522) was recorded in 2016, while the highest incidence rate (62.47) was recorded in 2008. Interestingly, both the number of episodes and incidence rate were shown to decrease in 2020 and 2021, likely due to changes in public health behavior and reporting during the COVID-19 pandemic; however, both increased again in 2022 and 2023. Typhoid and paratyphoid cases were high from 2000 to 2005, with incidence rates ranging from 1.93 to 4.10. However, from 2006 to 2023, the incidence rates declined, ranging from 0.28 to 0.35. To date, there remains limited information regarding the total number of cases and incidence rates for the NTS salmonellosis, as well as the overall number of salmonellosis (typhoid and NTS salmonellosis) cases in Malaysia.

Foodborne outbreaks in Malaysia

Several notable outbreaks of food poisoning have been reported in Malaysia since 2003, and at least four outbreaks resulted in deaths (Table 1). The most recent outbreak occurred in 2025, with 427 cases (Free Malaysia Today, 2025). The latest outbreak with fatalities occurred in 2024, involving individuals who consumed eggs and vermicelli for breakfast in a school program (NewStraitsTimes, 2024). A total of 84 people suffered from the food poisoning, and two deaths were reported. In 2018, an outbreak linked to the consumption of *Laksa Kebok* from a street vendor affected approximately 83 people and resulted in two deaths (Abdul-Rahman *et al*., 2022). Another fatal case occurred in 2014 in Terengganu, involving an individual who had consumed food purchased from a night market (Ab Karim *et al*., 2017; Astro Awani, 2014). In 2013, an outbreak was reported affecting 239 people following a wedding ceremony where four deaths occurred (The Star, 2013). Based on the investigation, one of the foods served during the wedding was a chicken dish or locally known as a*yam masak merah,* and was suggested to be the likely source of infection. On the contrary, while other reported outbreaks did not result in fatalities, they still affected a large number of people (Table 1). Most of these outbreaks resulted from eating foods during a large gathering (Latip *et al*., 2015; Rajakrishnan *et al*., 2022; The Star, 2013; Wan Mansor *et al*., 2003), in a school setting (Bujang *et al*., 2023; Free Malaysia Today, 2025; Koris, 2016; NewStraitsTimes, 2024) and from street vendors (Ab Karim *et al*., 2014; Abdul-Rahman *et al*., 2022; Astro Awani, 2014).

Several bacterial pathogens have been identified as the causative agents of food poisoning outbreaks in Malaysia. These include *Salmonella, Bacillus cereus, Staphylococcus aureus,* coliforms and *E. coli*. It is noteworthy to know that outbreaks resulting in fatalities were mainly caused by *Salmonella* species (Abdul-Rahman *et al*., 2022; Ab Karim *et al*., 2014; Astro Awani, 2014; NewStraitsTimes, 2024; The Star, 2013). In the 2018 outbreak, *Salmonella enterica* serovar Weltevreden was identified as the causative agent. This strain was isolated from both the stool samples of affected patients and the contaminated dish, *Laksa Kebok* (Abdul-Rahman *et al*., 2022). In the 2014 outbreak, *S.* Typhimurium (detected in the patients' stools) was identified to be the pathogen responsible for food poisoning that resulted in one death (Ab Karim, 2014; Astro Awani, 2014). However, the specific *Salmonella* serovars responsible for outbreaks in 2013 and 2024 were not determined (NewStraitsTimes, 2024; The Star, 2013).

Source of contamination

Salmonella is commonly found in a wide range of food sources, including animal-derived and plant-based, as well as in the environment and other non-food sources. In Malaysia, *Salmonella* has been detected in various animals and their products such as fish, shrimp, chicken, beef, pigs and duck meats (Table 2). It has also been reported in eggs and broiler chickens (Ibrahim *et al*., 2021; Ong *et al*., 2014; Rusul *et al*., 1996). In addition, the environments of both aquaculture and poultry processing facilities have shown to harbor *Salmonella* (Table 2). Non-food items also serve as potential sources of contamination. Several studies have reported the presence of *Salmonella* on food-contacts surfaces, such as tables, cutting knives, chopping boards, and containers used in wet markets (Sukri *et al*., 2021), as well as within poultry processing facilities (Nidaullah *et al*., 2017). *Salmonella* has also been detected in ready-to-eat (RTE) foods such as sushi, sashimi and battered meats products (Puah *et al*., 2016; Sandrasaigaran *et al*., 2023a).

A number of studies also reported the presence of *Salmonella* in plant-based foods such as leafy vegetables (Haslinda *et al*., 2022; Najwa *et al*., 2015; Salleh *et al*., 2003; Saw *et al*., 2020), fruit juices (Diana *et al*., 2012) and sliced fruits (Pui *et al*., 2011). *Salmonella* was also detected in filth flies at wet markets (Sandrasaigaran *et al*., 2023b), bird (Sem *et al*., 2024), dogs (Abatcha *et al*., 2014) and snake (Abatcha *et al*., 2013).

In human, *Salmonella* has been isolated from various clinical specimens such as stools, extra-intestinal, and blood samples (Table 2). The widespread presence of *Salmonella* across multiple contamination sources highlights its broad transmission pathways to humans, either directly or indirectly (Figure 2).

Serovars distribution

Several *Salmonella* serovars have been identified from various sources in Malaysia (Tables 2 and 3). *Salmonella* spp. were most frequently isolated from poultry and vegetables, with 40 and 44 different serovars identified, respectively. The most common serovars isolated from multiple sample types, including aquaculture and poultry meats and environments, vegetables, humans, and other sources were *S*. Typhimurium and *S*. Corvallis.

In addition, certain serovars were detected in specific source groups but were absent in others. *S*. Mikawashima and *S*. Poona were exclusively isolated in aquaculture (tilapia) and others sources (snake), respectively. There were 23, 22 and 15 unique serovars identified in poultry and environments, vegetables and fruits, and human, respectively.

Antibiotics resistance patterns

A total of 39 studies (Table 2) reported antimicrobial susceptibility testing (AST) of *Salmonella* isolates obtained from various sources in Malaysia. Of these, 31 studies (Table 2) reported high levels of resistance of *Salmonella* isolates ($\geq$50%) to multiple antibiotics (Figure 3). Among the antibiotics tested, erythromycin, penicillin, sulphonamide, cefuroxime, clindamycin, amoxicillin, vancomycin, rifampicin, and amikacin exhibited high resistance levels ($\geq$50%) in more than half of the studies that evaluated these antibiotics. Notably, all studies that assessed penicillin (Choe *et al*., 2011; de Lima *et al*., 2023; Devadas *et al*., 2025; Sing *et al*., 2016; Sukri *et al*., 2021; Thung *et al*., 2016; Thung *et al*., 2018) and clindamycin (Budiati *et al*., 2013; Choe *et al*., 2011; Sing *et al*., 2016) reported complete resistance (100%) of *Salmonella* isolates to these antibiotics. These resistant *Salmonella* isolates were isolated from diverse sources,

Table 1. The summary of salmonellosis outbreaks in Malaysia and the sources

No	Details	Food Implicated	Food Preparation Source	Causative Agents	Year	References
1.	**Private college in Kelantan** ● 427 cases among students, committee members, and staff following consumption of a catered meal at a private educational institution.	Chicken curry	External caterer	Suspected *Salmonella* spp.	2025	Free Malaysia Today, 2025
2.	**Gombak Food Poisoning** ● Community school program ● 247 attendees ● 82 people suffered from food poisoning ● Two deaths	Eggs Vermicelli	In-house/On-site prepared food	*Salmonella* spp. in stool samples	2024	NewStraitsTimes, 2024
3.	**Foodborne Illness Among Students in Boarding school, Negeri Sembilan** ● 597 students ● 152 cases were identified among students	Beef rendang (a dry curry) Rice Rice cubes Vermicelli	In-house/On-site prepared food -Boarding school canteen	*Bacillus cereus* Coliform *E. coli*	2021	Bujang *et al*., 2023
4.	**Mass Gathering, Petaling District, Selangor, Malaysia** ● 2,341 participants ● 169 were identified as cases ● 20 were admitted to hospital, the remaining as outpatients	*Nasi lemak* Bread Rice Chicken	In-house/On-site prepared food	*Bacillus cereus* *Staphylococcus aureus* Coliforms	2019	Rajakrishnan *et al*., 2022
5.	**Consumption of *Laksa Kebok* from a Stall in Baling, Kedah** ● 89 people consumed the *Laksa Kebok* ● Less than 10% of the cases were hospitalised ● Two deaths	*Laksa Kebok*	External caterer / Street vendor	*Salmonella* - *S*. Weltevreden - *S*. Typhi - *S*. Enteritidis - *S*. Livingstone - *S*. Agona *Staphylococcus aureus*	2018	Abdul-Rahman *et al*., 2022
6.	**Food Poisoning in Sekolah Menengah Sains Tapah, Perak** ● 63 cases (students and teachers)	*Roti jala* Chicken curry	In-house / On-site	*Salmonella* spp. *Bacillus cereus* *E. coli*	2016	Koris, 2016
7.	**Consumption of Food From Two Night Markets in Terengganu** ● 169 cases ● One death	White fried rice Red fried rice Fried kuey teow Fried noodles	External caterer / Street vendor	*S.* Typhimurium	2014	Ab Karim *et al*., 2017; Astro Awani, 2014
8.	**Wedding Banquet at Kedah** ● 170 sought health treatment ● 65 warded ● Four deaths	Chicken dish (*ayam masak merah*)	Mass catering/ external catering	*Salmonella* spp.	2013	The Star, 2013
9.	**Participants of Athlete Retreat at Teluk Keke** ● 20 cases	Shrimp curry	In-house / On-site	*E. coli*	2012	Latip *et al*., 2012
10.	**Typhoid Outbreak Following a Wedding Party in Kelantan** ● 1000 guests ● 477 experienced fever ● 152 cases	Syrup	In-house / On-site	*S*. Typhi	2003	Wan Mansor *et al*., 2003

In-house / On-site: Prepared within the institution, school, retreat, or event kitchen; outbreak likely due to storage, temperature abuse, or cross-contamination.
External caterer / Street vendor: Prepared by commercial vendors or external caterers; often involved large-scale distribution, multiple food items, and higher mortality.

Table 2. List of studies that conducted the detection of Salmonella in various sources and antimicrobial susceptibility testing

No.	Type of samples	*% of Salmonella* positivity and strains	Antimicrobial Susceptibility Testing				References
			Antibiotics	Resistant (%)	Intermediate (%)	Susceptible (%)	
			AQUACULTURE				
1.	**Shrimp aquaculture:** -Water -Shrimp	***Salmonella* (4.3%)** -*Salmonella* spp.	-Erythromycin -Penicillin -Azithromycin -Cephalexin -Ciprofloxacin -Neomycin -Kanamycin -Tetracycline -Chloramphenicol -Trimethoprim/Sulfamethoxazole -Ampicillin -Ceftriaxone	100 100 50 50 - - - - - - - -	- - 50 50 100 50 50 - - - - -	- - - - - 50 50 100 100 100 100 100	Devadas *et al*., 2025
2.	**Aquaculture:** -Tilapia -Asian seabass -Tilapia pond water -Asian seabass pond water	***Salmonella* (0.6%)** -*Salmonella* spp. -*S.* Typhimurium	-Erythromycin -Tetracycline -Ampicillin -Chloramphenicol -Cefotaxime -Ceftiofur	77.8 77.8 66.7 66.7 - -	22.2 - NA* - - -	- 22.2 NA* 33.3 100 100	Dewi *et al*., 2022
3.	**Retail farmed shrimp:** -Shrimp	***Salmonella* (60%)** -*Salmonella* spp.	-Erythromycin -Doxycycline -Tetracycline -Nalixidic acid -Ampicillin -Chloramphenicol -Gentamycin -Ciprofloxacin	100 77.8 72.2 61.1 55.6 44.4 16.7 16.7	NA* NA* NA* NA* NA* NA* NA* NA*	NA* NA* NA* NA* NA* NA* NA* NA*	Goh Ee *et al*., 2020
4.	**Fish Farm and wet markets:** -Catfish	***Salmonella* (20%)** -*S.* Corvallis -*S.* Mbandaka -*S.* Typhmurium	-Penicillin -Clindamycin -Tetracycline -Rifampicin -Ceftzaidine -Trimethoprim	100 100 100 100 - -	- - - - 16.67 -	- - - - 83.33 100	Sing *et al*., 2016
5.	**Wet markets and ponds:** -Catfish -Tilapia -Water	***Salmonella* (31.5%)** -*S.* Albany -*S.* Agona -*S.* Corvallis -*S.* Stanley -*S.* Typhimurium -*S.* Mikawashima -*S.* Bovis-mobificans	-Clindamycin -Rifampicin -Tetracycline -Chloramphenicol -Spectinomycin	100 90.7 67.4 37.2 27.9	NA NA NA NA NA	NA NA NA NA NA	Budiati *et al*., 2013
			POULTRY				
1.	**Slaughterhouse:** -Raw chicken meat	***Salmonella* (17.09%)** -*S.* Corvallis -*S.* Brancaster -*S.* Albany -*S.* Indiana -*S.* Cyprus -*S.* Braenderup -*S.* Typhimurium -*S.* Enteritidis -*S.* Bellevue -*S.* Duesseldorf -*S.* Hiduddify -*S.* Hindmarsh	-Erythromycin -Tetracycline -Trimethoprim/Sulfamethoxazole -Streptomycin -Ampicillin -Enrofloxacin -Nalidixic acid -Gentamicin -Cephalothin -Ceftriaxone -Amoxicillin/Clavulanic acid -Ciprofloxacin	87.41 85.19 55.55 29.63 26.63 22.96 17.04 7.41 5.96 3.70 2.22 -	11.85 3.7 12.6 14.07 0.74 35.56 42.22 0.74 2.22 0.74 2.22 -	0.74 11.11 31.85 56.30 69.63 41.48 40.74 91.85 91.85 95.56 95.56 100	Ismail *et al*., 2024

2.	**Retail chicken meat:** -Chicken meat	*Salmonella* (12.7%)	-Erythromycin	92.9	7.1	-	Rajaratnam & Mahyudin, 2024
			-Ampicillin	78.6	-	21.4	
			-Aztreonam	71.4	-	28.6	
			-Trimethoprim/Sulfamethoxazole	71.4	-	28.6	
			-Tetracycline	71.4	-	28.6	
			-Chloramphenicol	71.4	7.1	21.4	
			-Cefotaxime	35.7	42.9	21.4	
			-Nalidixic acid	35.7	42.9	21.4	
			-Streptomycin	28.6	-	71.4	
			-Cefepime	21.4	-	64.3	
			-Ceftazidime	21.4	21.4	57.1	
			-Cephalothin	21.4	14.3	64.3	
			-Gentamicin	14.3	21.4	64.3	
			-Ceftriaxone	14.3	42.9	42.9	
			-Enrofloxacin	7.1	42.9	50.0	
			-Amoxicillin/Clavulanic-acid	-	14.3	85.7	
			-Ciprofloxacin	-	14.3	85.7	
			-Doxycycline	-	57.1	42.9	
3.	**Farm and abattoirs:** -Chicken cloacal swabs -Raw chicken meat	*S.* Brancaster	-Ampicillin	91	NA	NA	Khoo *et al.*, 2023
			-Tetracycline	86	NA	NA	
			-Trimethoprim/Sulfamethoxazole	62	NA	NA	
			-Chloramphenicol	61	NA	NA	
			-Gentamicin	45	NA	NA	
			-Nalidixic acid	43	NA	NA	
			-Streptomycin	33	NA	NA	
			-Ciprofloxacin	9	NA	NA	
			-Amoxicillin/Clavulanic acid	4	NA	NA	
4.	**Poultry farm environments:** -Soil -Effluent samples	***Salmonella* (38.1%)** -*S.* Weltevreden -*S.* Jedburgh -*S.* Brancaster	-Cefazolin	95.8	4.2	-	Thahir *et al.*, 2023
			-Cefuroxime	95.8	4.2	-	
			-Cefoxitin	95.8	4.2	-	
			-Amikacin	95.8	4.2	-	
			-Gentamicin	95.8	4.2	-	
			-Ampicillin	62.5	-	37.5	
			-Ampicillin/Sulbactam	50	12.5	37.5	
			-Ciprofloxacin	33.3	16.7	50	
			-Trimethoprim/Sulfamethoxazole	12.5	-	87.5	
			-Nitrofurantoin	4.2	12.5	83.3	
			-Amoxillin/Clavulanic Acid	-	4.2	95.8	
			-Piperacillin/Tazobactam	-	-	100	
			-Cefotaxime	-	-	100	
			-Ceftazidime	-	-	100	
			-Ceftriaxone	-	-	100	
			-Cefepime	-	-	100	
			-Meropenem	-	-	100	
			-Aztreonam	-	-	100	
5.	**Poultry meat-processing plants:** -Raw meat -Processed meat	***Salmonella* (2.1%)** -*Salmonella* spp.	-Ampicillin	100	NA	NA	Subramaniam *et al.*, 2023
			-Chloramphenicol	87.0	NA	NA	
			-Cefuroxime	60.9	NA	NA	
			-Cefazolin	56.5	NA	NA	
			-Kanamycin	52.2	NA	NA	
			-Ceftazidime	47.8	NA	NA	
			-Sulfonamides	43.5	NA	NA	
			-Ceftriaxone	34.8	NA	NA	
			-Ciprofloxacin	21.7	NA	NA	
			-Nalidixic Acid	21.7	NA	NA	
			-Cefoxitin	21.7	NA	NA	
			-Tetracycline	13.0	NA	NA	
6.	**Poultry farms, retails store and food vendors:** -Ready-to-eat chicken meat -Raw chicken meat -Cloacal swabs	*S.* Enteritidis	-Tetracycline	44.4	NA	NA	Zakaria *et al.*, 2022
			-Ampicillin	13.3	NA	NA	
			-Chloramphenicol	2.2	NA	NA	
			-Gentamicin	2.2	NA	NA	
			-Streptomycin	2.2	NA	NA	
			-Trimethoprim/Sulfamethazine	2.2	NA	NA	
			-Ceftiofur	-	NA	NA	
			-Cefotaxime	-	NA	NA	
			-Ciprofloxacin	-	NA	NA	

7.	**Broilers farms:**	***Salmonella* (6.6%)**	-Erythromycin	100	-	-	Ibrahim *et al*., 2021
		-*Salmonella* spp.	-Chloramphenicol	76.2	-	23.8	
	-Cloacal swab from broilers		-Tetracycline	62	-	38	
			-Ampicillin	47.7	-	52.3	
			-Trimethoprim/Sulfamethoxazole	42.9	-	57.1	
			-Kanamycin	28.6	-	71.4	
			-Streptomycin	19	-	76.1	
			-Nalidixic acid	9.6	-	90.4	
			-Ciprofloxacin	4.8	-	95.2	
			-Gentamicin	-	-	100	
			-Cephalothin	-	-	100	
			-Colistin sulphate	-	-	100	
8.	**Wet markets:**	***Salmonella* (35%)**	-Erythromycin	100	-	-	Sukri *et al*., 2021
		-*S. enterica* Group 1	-Penicillin	100	-	-	
	-Chicken meat		-Chloramphenicol	100	-	-	
	-Contact surfaces: Tables, cutting knife, chopping board, container		-Tetracycline	100	-	-	
			-Trimethoprim/Sulfamethoxazole	57.1	-	42.9	
			-Amoxicillin	57.1	-	42.9	
			-Ampicillin	57.1	-	42.9	
			-Cephalexin	14.3	-	85.7	
			-Cefotaxime	14.3	-	85.7	
			-Cefoxitin	14.3	-	85.7	
			-Ceftriaxone	14.3	-	85.7	
9.	**Village chickens:**	***Salmonella* spp.**	-Tetracycline	35.3	2.9	61.8	Jajere *et al*., 2020
		-*S.* Weltevreden	-Streptomycin	35.3	32.4	32.4	
	-Cloacal swabs	-*S.* Typhimurium	-Sulfonamides	29.4	-	70.6	
	-Feed	-*S.* Agona	-Trimethoprim	20.6	-	79.4	
	-Drinking water	-*S.* Enteritidis	-Ampicillin	17.6	-	82.4	
	-Flies	-*S.* Albany	-Colistin	14.7	-	85.3	
		-*S.* Molade	-Nalidixic acid	14.7	-	85.3	
		-*S.* Corvallis	-Chloramphenicol	11.8	-	88.2	
		-*S.* Schleissheim	-Nitrofurantoin	11.8	-	88.2	
			-Amoxicillin/Clavulanate	5.9	5.9	88.2	
			-Kanamycin	2.9	5.9	91.2	
			-Cefotaxime	2.9	-	97.1	
			-Ceftiofur	-	2.9	97.1	
			-Gentamicin	-	2.9	97.1	
			-Norfloxacin	-	2.9	97.1	
			-Ciprofloxacin	-	-	100	
10.	**Poultry and retail outlets:**	*S.* Enteritidis	-Tetracycline	46.8	NA	NA	Zakaria *et al*., 2020
			-Ampicillin	14.8	NA	NA	
	-Ready-to-eat chicken meat		-Streptomycin	2.1	NA	NA	
	-Raw chicken meat		-Sulfadimidine/Trimethoprim	2.1	NA	NA	
	-Cloacal swabs		-Gentamycin	2.1	NA	NA	
11.	**Wet market and hypermarket:**	***Salmonella* (64.63%)**	-Cephalothin	100	-	-	Tan *et al*., 2019
		-*Salmonella* spp.	-Trimethoprim/Sulfamethoxazole	50	-	50	
	-Raw beef		-Tetracycline	50	-	50	
			-Nalidixic acid	25	25	50	
			-Ceftazidime	25	25	50	
			-Streptomycin	25	25	50	
			-Ceftriaxone	25	-	75	
			-Ciprofloxacin	-	25	75	
			-Imipenem	-	-	100	
			-Gentamicin	-	-	100	
			-Chloramphenicol	-	-	100	
			-Kanamycin	-	-	100	
12.	**Retails:**	***Salmonella* (19.2%)**	-Erythromycin	100	-	-	Thung *et al*., 2018
		-*S.* Enteritidis	-Penicillin	100	-	-	
	-Beefs meat	-*S.* Typhimurium	-Vancomycin	100	-	-	
			-Ampicillin	47.83	34.78	17.39	
			-Chloramphenicol	30.43	56.52	13.05	
			-Ciprofloxacin	21.74	21.74	56.52	
			-Amoxycillin	17.39	17.39	65.22	
			-Trimethoprim/Sulfamethoxazole	17.39	26.09	56.22	
			-Cephazolin	8.70	8.70	82.60	
			-Ceftazidime	-	21.74	78.26	
			-Kanamycin	-	8.70	91.30	
			-Nalidixic acid	-	8.70	91.30	
			-Streptomycin	-	8.70	91.30	
			-Amoxicillin/Clavulanic acid	-	-	100	
			-Gentamicin	-	-	100	
			-Tetracycline	-	-	100	

13.	**Poultry environments:** -Chicken cuts -Food contact surfaces (knife, drum, cutting board) -Environmental samples: apron, bench wash water, drain water, drain swab, floor)	***Salmonella*** -*S.* Corvallis -*S.* Brancaster -*S.* Albany	-Sulphonamide -Ampicillin -Tetracycline -Chloramphenicol -Trimethoprim -Trimethoprim/Sulfamethoxazole -Streptomycin -Nalidixic acid -Cephalothin -Ampicillin/Sulbactam -Gentamicin -Ciprofloxacin -Ceftriaxone	96.5 89.5 85.1 75.4 68.4 67.5 58.8 45.6 10.5 9.7 6.1 3.5 -	NA NA NA NA NA NA NA NA NA NA NA NA NA	NA NA NA NA NA NA NA NA NA NA NA NA NA	Chuah *et al*., 2018
14.	**Poultry processing environments:** -Whole chicken carcass, chicken cuts, transport crate, cage, drum, knife, chopping board, display table, floor, bench wash water, wash water, drain water	***Salmonella* (88.46%)** -*S.* Albany -*S.* Corvallis -*S.* Brancaster -*S.* Enteritidis -*S.* Typhimurium -*S.* Florian -*S.* Braenderup -*S.* Give -*S.* Weltevreden -*S.* Kivu -*S.* Sarajane -*S.* Haifa -*S.* Indiana -S. Kentucky -*S.* Oyonnax -*S.* Chester -*S.* Stanley	NA	NA	NA	NA	Nidaullah *et al*., 2017
15.	**Poultry farm and wet markets:** -Spent hen	***Salmonella* (14.0%)** -*S.* Corvallis -*S.* Typhimurium -*S.* Braenderup -*S.* Albany -*S.* Mbandaka -*S.* Schwarzengrund -*S.* Potsdam -*S.* Enteritidis -*S.* Virginia -*S.* Muenchen -*S.* Agona	-Erythromycin -Tetracycline -Streptomycin -Trimethoprim/Sulfamethoxazole -Ampicillin -Chloramphenicol -Nalidix acid -Gentamicin -Kanamycin -Ciprofloxacin -Cephalothin -Polymyxin B -Cefriaxone	97 93.9 66.7 57.6 31.8 30.3 30.3 25.8 22.7 7.6 3.0 1.5 0	NA NA NA NA NA NA NA NA NA NA NA NA -	NA NA NA NA NA NA NA NA NA NA 97.0 98.5 100	Deli & Adzitey, 2017
16.	**Retail outlets:** -Chicken and beef meats	***Salmonella* (27.6%)** -*S.* Enteritidis -*S.* Hadar -*S.* Dublin -*S.* Anatum -*S.* Stanley -*S.* Gallinarum -*S.* Choleraesuis -*S.* Typhimurium	NA	NA	NA	NA	Shafini *et al*., 2017
17.	**Wet markets and hypermarkets:** -Chicken meats	***Salmonella* (30%)** -*S.* Enteritidis -*S.* Typhimurium	-Erythromycin -Penicillin -Vancomycin -Ampicillin -Amoxycillin -Cephazolin -Ciprofloxacin -Nalidixic acid -Streptomycin -Ceftazidime -Amoxicillin/Clavulanic acid -Gentamicin -Tetracycline -Trimethoprim	100 100 100 72.73 27.27 27.27 27.27 9.09 9.09 - - - - -	- - - 27.77 - 18.18 72.73 27.27 27.27 27.27 - - - -	- - - - 72.73 54.55 - 63.64 63.64 72.73 100 100 100 100	Thung *et al*., 2016

18.	**Poultry environment:** -Eggs, -cloacal/faecal swabs -environmental samples -feed -water	***Salmonella* (11.9%)** -*S.* Enteritidis -*S.* Typhimurium	NA	NA	NA	NA	Ong *et al.*, 2014
19.	**-Ducks rearing and processing:** -Ducks -Rearing -Processing environment	***Salmonella* (23.5%)** -*S.* Typhimirium -*S.* Enteritidis -*S.* Gallinarum -*S.* Braenderup -*S.* Albany -*S.* Hadar -*S.* Derby -*S.* Weltevreden -*S.* Newbrunswick -*S.* London	-Erythromycin -Nalidixic acid -Tetracycline -Choramphenicol -Trimethoprim/Sulfamethoxazole -Streptomycin -Ampicillin -Cephalothin -Norfloxacin -Cefotaxime -Cefriaxone -Gentamicin -Ciprofloxacin	100 73.6 71.2 37.6 37.6 29.6 24 4.8 1.6 0.8 - - -	- NA NA NA NA NA NA NA NA NA - - -	- NA NA NA NA NA NA NA NA NA 100 100 100	Adzitey *et al.*, 2012
20.	**Pig farms:** -Finishing pigs	*S.* Typhimurium (15.2%)	-Clindamycin -Penicillin -Sulphamethoxazole -Tetracycline -Chloramphenicol -ChlorTetracycline -OxyTetracycline -Pefloxacin -Cephalothin -Cephradine -Amoxycillin -Ampicillin -Carbenicillin -Colistin sulphate -Neomycin -Enrofloxacin -Ciprofloxacin -Amikacin -Amoxicillin/Clavulanic acid -Apramycin -Cephalexin -Fosfomycin -Gentamicin -Kanamycin -Norfloxacin	100 100 100 100 87.5 87.5 87.5 43.8 43.8 34.4 21.8 21.8 12.5 12.5 - - - - - - - - - - -	- - - - 12.5 12.5 12.5 56.2 34.4 65.6 56.4 12.5 53.1 - 65.6 34.4 21.8 - - - - - - - -	- - - - - - - - 21.8 - 21.8 65.6 34.4 87.5 34.4 65.6 78.2 100 100 100 100 100 100 100 100	Choe *et al.*, 2011
21.	**Backyard chicken shed:** -Eggs (Free-range (FR) and Commercial (CL))	***Salmonella* (10.1%)** -*Salmonella* spp.	-Erythromycin -Ampicillin -Sulphonamide -Nalidixic Acid -Streptomycin -Cephradine -Cephalothin -Ciprofloxacin -Enrofloxacin	100 *FR* -*CL* 75 *FR* 100 *CL* 75 *FR* 100 *CL* 50 *CL* 100 *FR* - *CL* 100 *FR* 50 *CL* 25 *FR* 50 *CL* 25 *FR* - *CL* - *FR* - *CL* - *FR*	NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA	NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA	Hassan *et al.*, 2005

22.	**Wet markets, processing plants and broilers farms:** -Broilers -Litter and feed samples	**Predominant serovars** -*S.* Enteritidis (35.2%) -*S.* Muenchen (20.0%) -*S.* Kentucky (14.3%) -*S.* Blockley (10.4%)	NA	NA	NA	NA	Rusul *et al*., 1996
			VEGETABLES				
1.	**Farms and retail markets:** -Salad vegetables: Cosmos, water parsley, pennywort, cucumber, sissoo spinach -Irrigation water -Soil	***Salmonella* (8.71%)** -*S.* Weltevreden -*S.* Albany -*S.* Hvittingfoss -*S.* Aberdeen	-Ampicillin -Tetracycline -Doxycycline -Trimethoprim/Sulfamethoxazole -Chloramphenical -Azithromycin -Minocycline -Amoxicillin/Clavulanic acid -Ampicillin/Sulbactam -Aztreonam -Cefoperazone -Cefepime -Cefriaxone -Cefotaxime -Colistin -Ceftazidime -Ertapenem -Meropenem -Piperacillin/Tazobactam -Imipenem	20.69 18.97 17.24 17.24 15.52 8.62 8.62 6.9 5.17 5.17 5.17 5.17 3.45 3.45 3.45 1.72 1.72 - - -	- 5.17 1.72 - - - 5.17 5.17 8.62 1.72 10.34 5.17 - - - - - 3.45 - -	79.31 75.86 81.03 82.76 84.48 91.38 86.21 87.53 86.21 93.10 84.48 94.83 96.55 96.55 96.55 98.28 98.28 96.55 100 100	Haslinda *et al*., 2022
2.	**Hypermarkets and wet market:** -Cabbages -Cucumbers	***Salmonella* (5.6%)** -*Salmonella* spp. -*S.* Typhimurium	NA	NA	NA	NA	Saw *et al*., 2020
3.	**Fresh food markets:** -Raw leafy vegetables -Chicken carcasses -Related environments	***Salmonella* (29.1%)** -*S.* Corvallis -*S.* Brancaster -*S.* Weltevreden -*S.* Albany -*S.* Hvittingfoss -*S.* Paratyphi B -*S.* Typhimurium -*S.* Indiana -*S.* Aberdeen -*S.* Augustenborg -*S.* Richmond -*S.* Mbandaka -*S.* Enteritidis -*S.* Braenderup -*S.* Give -*S.* Redhill -*S.* Dusseldorf -*S.* Dumfries -*S.* Newport -*S.* Stanley -*S.* Planckendael -*S.* Bareilly -*S.* Cerro -*S.* Djugu -*S.* Gamira -*S.* Haifa -*S.* Kastrup -*S.* Kentucky -*S.* Lindenburg -*S.* Minnesota -*S.* Mkamba -*S.* Molade -*S.* Obugu -*S.* Ohio -*S.* Salamae (II,19,12,lv,z39) -*S.* Tudu -*S.* Wandsworth	-Streptomycin -Tetracycline -Sulfonamides -Ampicillin -Chloramphenicol -Trimethoprim/Sulfamethoxazole -Nalidix acid -Kanamycin -Cephalothin -Gentamycin -Amoxicillin/Clavulanate -Ciprofloxacin	62.6 44.3 44.3 26.7 21.9 16.6 12.8 11.2 4.8 3.2 2.1 -	NA NA NA NA NA NA NA NA NA NA NA NA	NA NA NA NA NA NA NA NA NA NA NA NA	Abatcha *et al*., 2018

4.	**Hypermarket and vegetable farm:** -Carrot -Eggplant	*S.* Enteritidis	-Ampicillin -Amoxicillin -Trimethoprim -Nalidixic acid -Trimethoprim/Sulfamethoxazole -Chloramphenicol -Ceftriaxone -Amoxicillin/Clavulanic acid -Ciprofloxacin -Ceftazidime -Gentamicin -Tetracycline	100 100 100 75 75 66.7 33.3 8.3 - - - -	- - - 25 25 33.3 50 75 50 - - -	- - - - - - 8.3 16.7 50 100 100 100	Kuan *et al*., 2017
5.	**Retail markets:** -Raw vegetables: Asiatic pennywort, water dropwort, long bean, winged bean	***Salmonella* (97.9%)** -*S.* Enteritidis -*S.* Typhimurium	-Ampicillin -Erythromycin -Amoxicillin/Clavulanic acid -Cephalothin -Ciprofloxacin -Streptomycin -Nalidixic acid -Tetracycline -Chloramphenicol -Trimethoprim/Sulfamethoxazole -Gentamicin	100 100 81.3 75 50 50 12.5 12.5 6.3 6.3 -	- - NA NA NA NA NA NA NA NA -	- - NA NA NA NA NA NA NA NA 100	Najwa *et al*., 2015
6.	**Indigenous vegetables:** -Selom	***Salmonella*** -*S.* Agona -*S.* Brunei -*S.* Bovismorbificans -*S.* Matopeni -*S.* Stanley -*S.* Paratyphi B -*S.* Richmond -*S.* Seftenberg -*S.* Sada -*S.* Newport -*S.* Mbandaka -*S.* Albany -*S.* Typhimurium -*S.* Weltevreden	-Erythromycin -Tetracycline -Streptomycin -Ceftriaxone -Trimethoprim-sulphamethoxazole -Cefuroxime -Nalidixic acid -Gentamycin -Cefotaxime -Chloramphenicol	100 27 20 14 14 12 12 9 7 3	NA NA NA NA NA NA NA NA NA NA	NA NA NA NA NA NA NA NA NA NA	Learn-Han *et al*., 2009
7.	**Hawker stalls:** -Fruit juice	***Salmonella* (34%)** -*S.* Typhi -*S.* Typhimurium	NA	NA	NA	NA	Diana *et al*., 2012
8.	**Hawker stalls and hypermarkets:** -Sliced fruits	***Salmonella* (23.3%)** -*S.* Typhi -*S.* Typhimurium	NA	NA	NA	NA	Pui *et al*., 2010
9.	**Wet markets:** -Selom, pegaga, kangkong, kesum	***Salmonella* (35%)** -*S.* Weltevreden -*S.* Agona -*S.* Seftenberg -*S.* Albany	NA	NA	NA	NA	Salleh *et al*., 2003
STREET FOODS/READY-TO-EAT FOODS							
1.	**Battered street foods:** -Chicken -Fish -Beef -Pork	***Salmonella*** -*S.* Enteritidis (5.1%) -*S.* Typhimurium (1.6%)	-Ampicillin -Cefazolin -Streptomycin -Ciprofloxacin -Kanamycin -Sulfonamides -Tetracycline -Nalidixic acid -Chloramphenicol -Gentamicin	21.1 21.1 21.1 15.8 15.8 15.8 15.8 15.8 5.3 5.3	42.1 - 68.4 84.2 68.4 47.3 - 15.8 26.3 57.9	36.8 78.9 10.5 - 15.8 36.8 84.2 68.4 68.4 36.8	Sandrasaigaran *et al*., 2023a

2.	**Retails outlets:** -Ready to eat food (sushi, sashimi)	*S. enterica* (16%)	-Sulfamethoxazole	50	NA	NA	Puah *et al*., 2016
			-Ampicillin	31.3	NA	NA	
			-Tetracycline	28.1	NA	NA	
			-Ceftazidime	28.1	NA	NA	
			-Ceftriaxone	25	NA	NA	
			-Streptomycin	25	NA	NA	
			-Nalidixic acid	25	NA	NA	
			-Trimethoprim/Sulfamethoxazole	25	NA	NA	
			-Chloramphenicol	25	NA	NA	
			-Amoxicillin/Clavulanic acid	21.9	NA	NA	
			-Cefoxitin	21.9	NA	NA	
			-Kanamycin	18.8	NA	NA	
			-Gentamicin	9.4	NA	NA	
			-Ciprofloxacin	9.4	NA	NA	
OTHERS							
1.	**Petting zoos:** -Psittacine birds (Fresh faecal)	*Salmonella* (7.5%)	-Amoxicillin/Clavulanic Acid	100	-	-	Sem *et al*., 2024
			-Ampicillin	100	-	-	
			-Ceftiofur	66.7	-	33.3	
			-Cefotaxime	66.7	-	33.3	
			-Nalidixic Acid	33.3	-	66.7	
			-Sulphonamides	33.3	-	66.7	
			-Tetracycline	33.7	-	66.7	
			-Streptomycin	33.3	33.3	33.3	
			-Chloramphenicol	33.3	33.3	33.3	
			-Ciprofloxacin	-	-	100	
			-Gentamycin	-	-	100	
			-Norfloxacin	-	-	100	
2.	**Animal wards:** -Environmental: Walls, floors, feed and water buckets, cleaning equipment	*Salmonella* spp.	-Penicillin	100	-	-	de Lima *et al*., 2023
			-Enrofloxacin	100	-	-	
			-Streptomycin	16.6	-	83.3	
			-Gentamicin	16.6	-	83.3	
3.	**Wet markets:** -Filth flies	***Salmonella* (17.8%)** -*S.* Enteritidis -*S.* Typhimurium -*S. enterica* subsp. I.	-Ampicillin	100	-	-	Sandrasaigaran *et al*., 2023b
			-Chloramphenicol	50	NA	NA	
			-Kanamycin	37.5	NA	NA	
			-Streptomycin	37.5	NA	NA	
			-Nalidixic acid	25	NA	NA	
			-Gentamycin	12.5	NA	NA	
			-Tetracycline	6.25	NA	NA	
			-Cefazolin	-	-	100	
			-Ciprofloxacin	-	-	100	
			-Ceftriaxone	-	-	100	
			-Sulfonamides	-	-	100	
4.	**Stray and pet dogs:** -Rectal swab	***Salmonella* (9.3%)** -*S.* Corvallis -S. Typhimurium -*S.* Mbandka -*S.* Agona	-Tetracycline	86.7	NA	NA	Abatcha *et al*., 2014
			-Ampicillin	40	NA	NA	
			-Sulphamethazole-TriM	40	NA	NA	
			-Chloramphenicol	33.3	NA	NA	
			-Streptomycin	33.3	NA	NA	
			-Enrofloxacin	26.7	NA	NA	
			-Kanamycin	13.3	NA	NA	
			-Neomycin	13.3	NA	NA	
			-Cephalothin	13.3	NA	NA	
			-Gentamycin	-	NA	NA	
			-Cephalexin	-	NA	NA	
			-Amoxicillin/Clavulanic acid	-	NA	NA	
5.	**Reptile:** -Snake	***Salmonella*** -*S. enterica* -*S.* Typhimurium -*S.* Corvallis -*S.* Poona -*S.* Mbandaka	-Cephalexin	12.5	18.75	68.75	Abatcha *et al*., 2013
			-Cephalothin	12.5	18.75	68.75	
			-Amoxicillin/Clavulanic acid	6.25	12.5	81.25	
			-Neomycin	-	75	25	
			-Ampicillin	-	12.5	87.5	
			-Kanamycin	-	6.25	93.75	
			-Streptomycin	-	6.25	93.75	
			-Chloramphenicol	-	-	100	
			-Gentamycin	-	-	100	
			-Enrofloxacin	-	-	100	
			-Trimethoprim/Sulfamethoxazole	-	-	100	
			-Tetracyclin	-	-	100	

			HUMAN				
1.	Humans and animals samples	*S.* Enteritidis	-Nalidixic acid -Tetracycline -Ampicilline -Sulfonamide -Trimethoprim/Sulfamethoxazole -Trimethoprim -Cephalothin -Amoxicillin/Clavulanic acid -Streptomycin -Ceftriaxone -Ceftazidime -Cefotaxime -Kanamycin -Gentamicin -Chloramphenicol	49 43 35 30 24 23 11 6 3 3 2 2 2 1 1	NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA	NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA	Ngoi & Thong, 2013
2.	**Human:** -Stool -Extra-intestinal	***Salmonella*** -*S.* Enteritidis -*S.* Corvallis -*S.* Braenderup -*S.* Farsta -*S.* Typhi -*S.* Weltevreden -*S.* Lagos -*S.* Tshiongwe -*S.* Albany -*S.* Biafra -*S.* Eppendorf -*S.* Hato -*S.* Limete -*S.* Rissen -*S.* Sandiego -*S.* Paratyphi A -*S.* Typhimurium	-Tetracycline -Sulphonamide -Streptomycin -Trimethoprim -Nalidix acid -Trimethoprim/Sulfamethoxazole -Cephalexin -Ampicillin -Kanamycin -Gentamicin -Ceftriaxone -Chloramphenicol -Cefotaxime -Ciprofloxacin	66.3 56.3 32.5 28.8 27.5 25 21.3 18.8 13.8 6.3 6.25 5 5 3.8	1.3 6.3 22.5 1.3 12.5 2.5 1.3 6.3 7.5 5 1.3 2.5 7.5 3.8	32.5 37.5 36 56 48 72.5 77.5 75 78.8 88.8 93.8 91.3 87.5 92.5	Thong *et al.*, 2011
3.	**Human:** -Stool -Blood samples	***Salmonella*** -*S.* Enteritidis -*S.* Typhimurium -*S.* Paratyphi B var Java -*S.* Weltevreden -*S.* Corvallis -*S.* Stanley -*S.* Braenderup -*S.* Albany -*S.* Thompson -*S.* Richmond -*S.* Lexington -*S.* Typhi -*S.* Newport -*S.* Paratyphi A -*S.* Bovismorbificans -*S.* Larochelle -*S.* Okatie -*S.* Matopeni -*S.* Muenchen -*S.* Infantis	-Cephalothin -Tetracycline -Nalidixic acid -Streptomycin -Ampicillin -Trimethoprim/Sulfamethoxazole -Chloramphenicol -Ceftiofur -Kanamycin -Gatifloxacin -Ceftazidime -Amoxicillin/Clavulanic acid -Amikacin -Gentamicin -Levofloxacin -Ciprofoxacin -Ceftriaxone -Cefotaxime -Imipenem	55.1 47.4 35.9 32.1 23.1 19.2 14.1 12.8 10.3 6.4 3.8 2.6 2.6 2.6 2.6 1.3 1.3 1.3 0	NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA	NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA NA	Tiong *et al.*, 2010
4.	**Human (children):** -Blood	1. UMMC -64 *Salmonella* isolates -42 *S.* Enteritidis	-Trimethprim/Sulfamethoxazole -Ampicilin -Chloramphenicol -Gentamicin -Cefriaxone	3 2 2 2 -	- - - - -	97 98 98 98 100	Lee *et al.*, 2003
		2. Hospital Kota Bharu, Kelantan -55 *Salmonella* isolates -44 *S.* Enteritidis	-Chloramphenicol -Tetracycline -Trimethprim/Sulfamethoxazole -Streptomycin -Ampicillin -Kanamycin	13 11 7 4 - -	- - - - - -	87 89 93 96 100 100	

Table 3. *Salmonella* serovars isolated from various sources in Malaysia

Aquaculture and environments	Poultry and environments	Vegetable and fruits	Others	Human
S. Agona	*S*. Agona	*S*. Aberdeen	*S*. Agona	*S*. Albany
S. Albany	*S*. Albany	*S*. Agona	*S*. Corvallis	*S*. Biafra
S. Bovismorbificans	*S*. Anatum	*S*. Albany	*S*. *enterica* subsp. I.	*S*. Braenderup
S. Corvallis	*S*. Bellevue	*S*. Augustenborg	*S*. Enteritidis	*S*. Bovismorbificans
S. Mbandaka	*S*. Blockley	*S*. Bareilly	*S*. Mbandka	*S*. Corvallis
S. Mikawashima	*S*. Brancaster	*S*. Brancaster	*S*. Poona	*S*. Enteritidis
S. Stanley	*S*. Braenderup	*S*. Braenderup	*S*. Typhimurium	*S*. Eppendorf
S. Typhimurium	*S*. Chester	*S*. Brunei		*S*. Farsta
	S. Choleraesuis	*S*. Bovismorbificans		*S*. Hato
	S. Corvallis	*S*. Cerro		*S*. Infantis
	S. Cyprus	*S*. Corvallis		*S*. Lagos
	S. Derby	*S*. Djugu		*S*. Lexington
	S. Dublin	*S*. Dumfries		*S*. Limete
	S. Duesseldorf	*S*. Dusseldorf		*S*. Larochelle
	S. Enteritidis	*S*. Enteritidis		*S*. Matopeni
	S. Florian	*S*. Gamira		*S*. Muenchen
	S. Gallinarum	*S*. Give		*S*. Newport
	S. Give	*S*. Haifa		*S*. Okatie
	S. Hadar	*S*. Hvittingfoss		*S*. Paratyphi A
	S. Haifa	*S*. Indiana		*S*. Paratyphi B var Java
	S. Hiduddify	*S*. Kastrup		*S*. Richmond
	S. Hindmarsh	*S*. Kentucky		*S*. Rissen
	S. Indiana	*S*. Lindenburg		*S*. Sandiego
	S. Jedburgh	*S*. Matopeni		*S*. Thompson
	S. Kentucky	*S*. Mbandaka		*S*. Stanley
	S. Kivu	*S*. Newport		*S*. Tshiongwe
	S. London	*S*. Minnesota		*S*. Typhi
	S. Mbandaka	*S*. Mkamba		*S*. Typhimurium
	S. Molade	*S*. Molade		*S*. Weltevreden
	S. Muenchen	*S*. Obugu		
	S. Newbrunswick	*S*. Ohio		
	S. Oyonnax	*S*. Paratyphi B		
	S. Potsdam	*S*. Planckendael		
	S. Sarajane	*S*. Redhill		
	S. Schwarzengrund	*S*. Richmond		
	S. Stanley	*S*. Sada		
	S. Schleissheim	*S*. Salamae (II,19,12,Iv,z39)		
	S. Typhimurium	*S*. Seftenberg		
	S. Virginia	*S*. Stanley		
	S. Weltevreden	*S*. Tudu		
		S. Typhi		
		S. Typhimurium		
		S. Wandsworth		
		S. Weltevreden		

including chicken meat, beef, ducks, broilers, contact surfaces, rearing and processing environments, fish, shrimp, birds, and raw vegetables.

Despite the high levels of resistance reported for certain antibiotics, 18 studies reported 100% susceptibility of *Salmonella* isolates to several antibiotics (Table 2). Piperacillin/tazobactam was shown to be fully effective (100%) in inhibiting *Salmonella* growth in two studies (Haslinda *et al*., 2022; Thahir *et al*., 2023) (Figure 4). In addition, a substantial proportion of studies (34.4%) reported complete susceptibility (100%) of *Salmonella* isolates to gentamicin. Some antibiotics, such as tetracycline, ampicillin and chloramphenicol, exhibited a wide ranges of antimicrobial activity against the *Salmonella* strains in Malaysia, with susceptibility levels varying from complete 100% susceptibility (Lee *et al*., 2003; Thung *et al*., 2018) to complete 100% resistance (Najwa *et al*., 2015; Sukri *et al*., 2021). Similarly, several antibiotics such as ceftriaxone, ciprofloxacin, cefotaxime, cefepime, kanamycin, cefazolin, and gentamicin showed 100% antimicrobial activity (Adzitey *et al*., 2012; Ibrahim *et al*., 2021; Ismail *et al*., 2024; Lee *et al*., 2003; Najwa *et al*., 2015; Sandrasaigaran *et al*., 2023a; Thahir *et al*., 2023; Thung *et al*., 2016; Thung *et al*., 2018). However, resistances to these antibiotics has also been reported, with resistance rates ranging from 0.8 to as high as 95.8% (Adzitey *et al*., 2012; Ibrahim *et al*., 2021; Ismail *et al*., 2024; Najwa *et al*., 2015; Rusul *et al*., 1996; Sandrasaigaran *et al*., 2023b; Sukri *et al*., 2021; Thahir *et al*., 2023; Thung *et al*., 2016; Thung *et al*., 2018).

DISCUSSION

Salmonellosis is a significant global public health issue affecting both humans and animals. It is a worldwide concern with notable variation in the number of *Salmonella* outbreaks across different countries and regions. Therefore, understanding the epidemiology of salmonellosis in every country is essential for the development and implementation of effective disease management and prevention strategies. In Malaysia, the number of food poisoning cases is consistently recorded each year. However, the recorded cases caused by *Salmonella* are primarily limited to typhoid and paratyphoid fevers. Although salmonellosis is also caused by the NTS, there remains a scarcity in knowledge and data on NTS

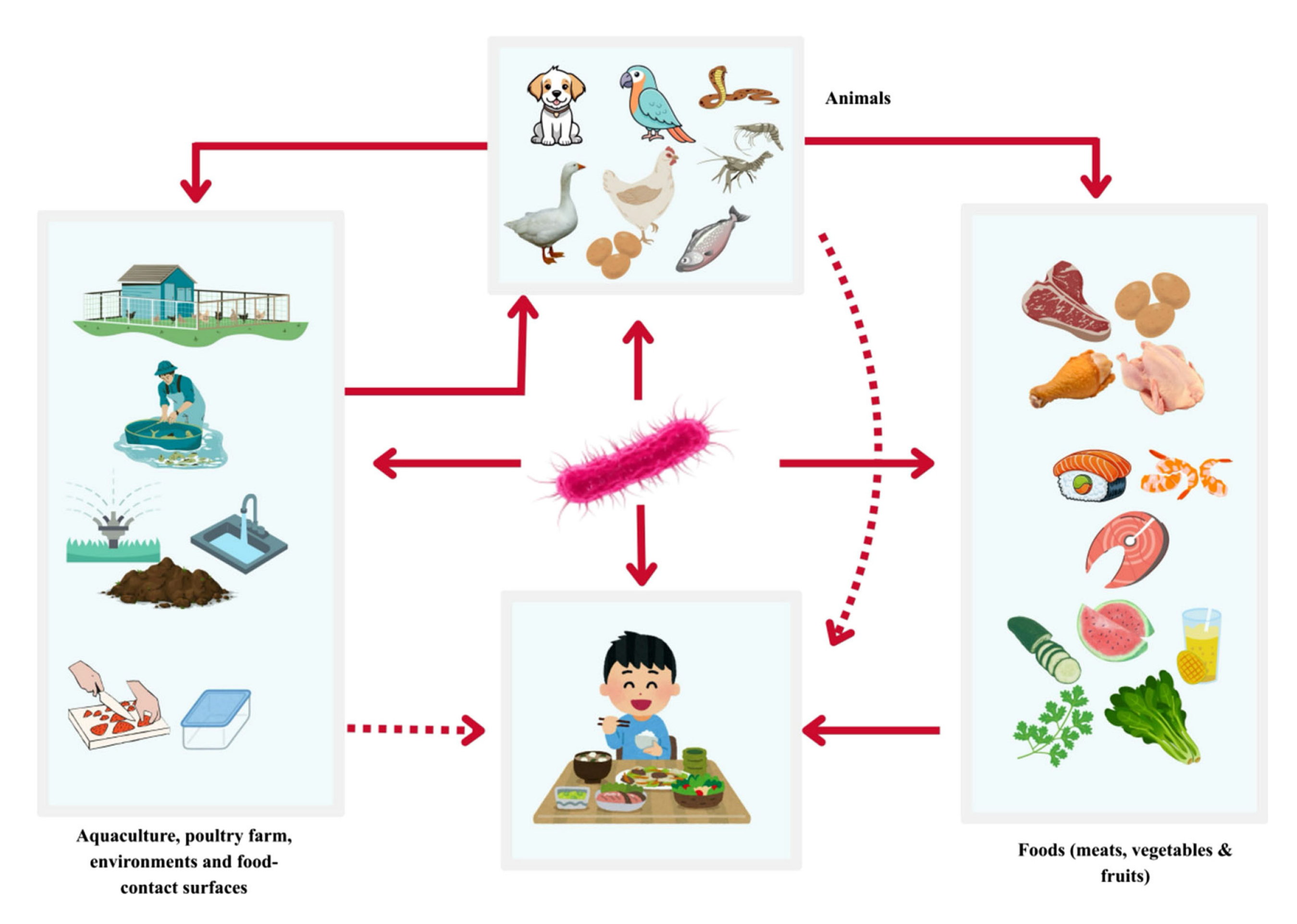

Figure 2. Transmission routes of *Salmonella* to humans. *Salmonella* can contaminate various sources, and humans may become infected through direct consumption of contaminated foods or indirect contact with contaminated environments and infected animals. Red solid arrows indicate direct *Salmonella* contamination, while dashed arrows represent indirect transmission pathways.

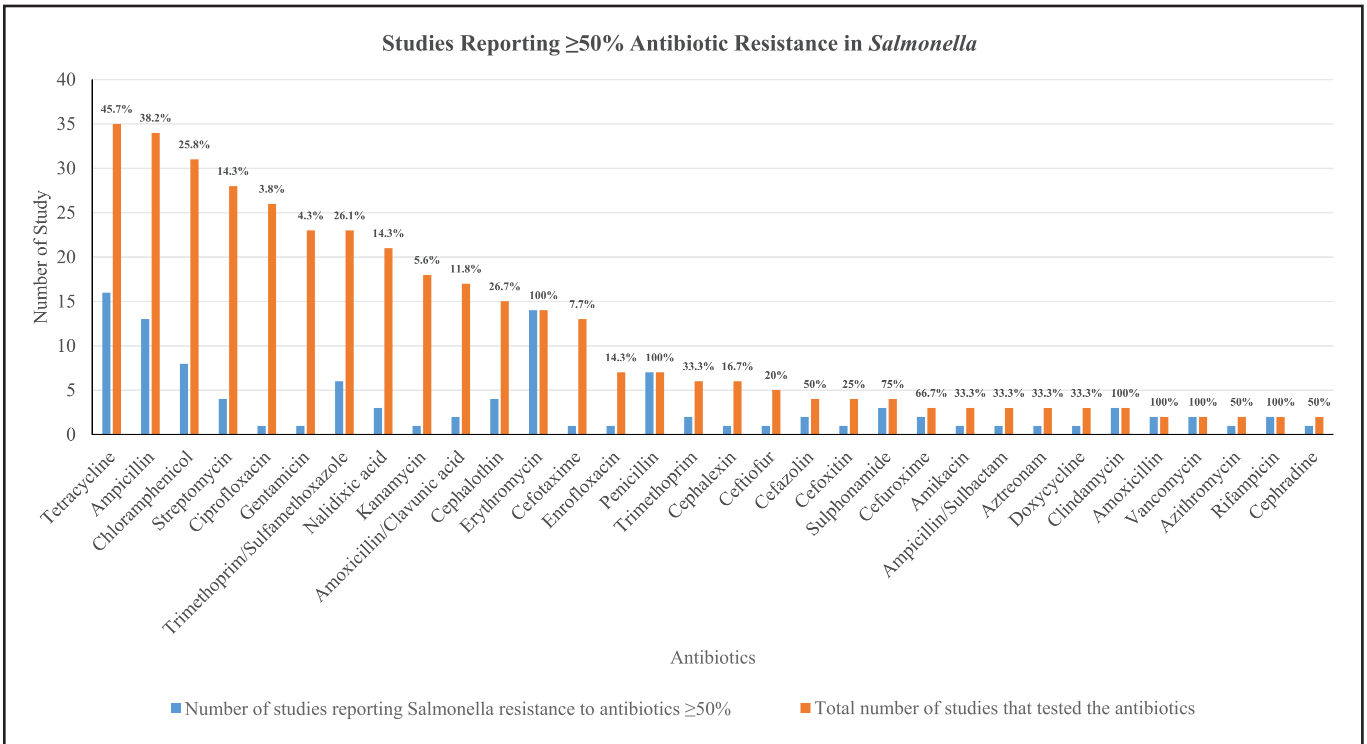

Figure 3. Number of studies reported the resistance (≥50%) of *Salmonella* isolates tot a range of antibiotics.

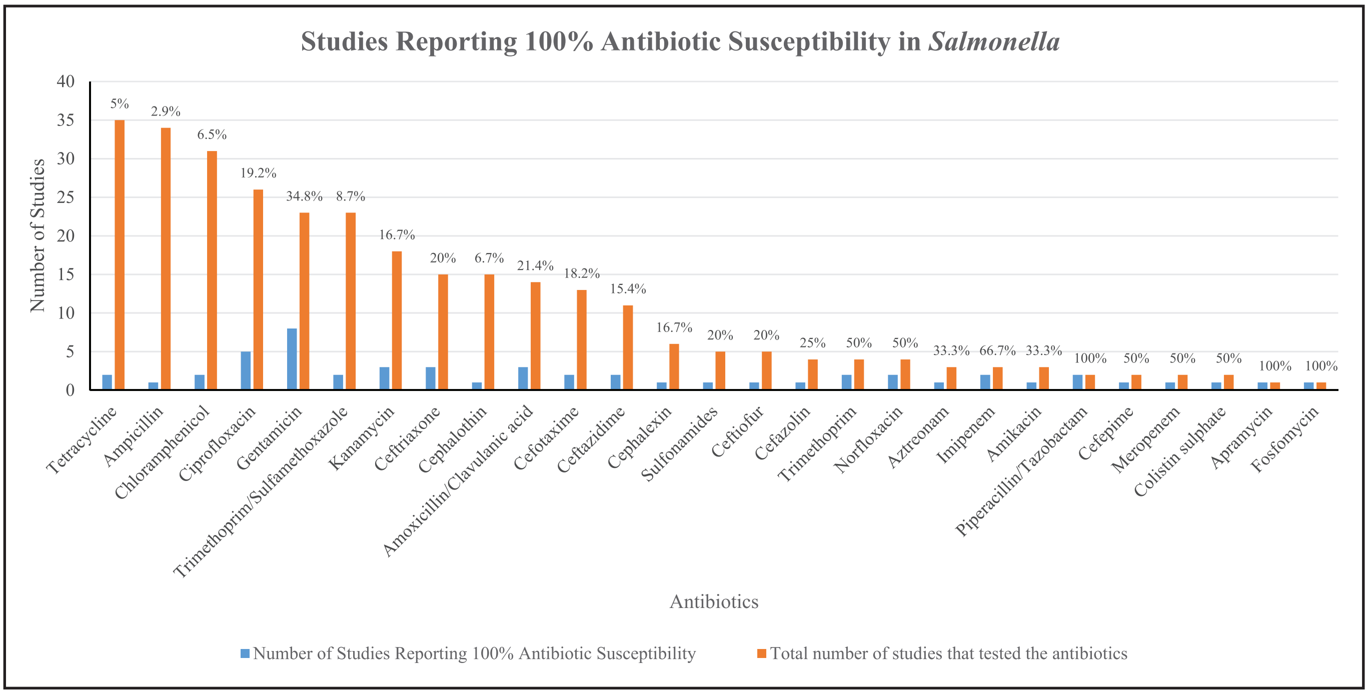

Figure 4. Number of studies reported the susceptibility (100%) of *Salmonella* isolates to a range of antibiotics.

salmonellosis in Malaysia. More concerning, the information on the total number of salmonellosis cases is also very limited. The lack of data on salmonellosis makes it challenging to estimate the disease burden in Malaysia. Globally, the number of salmonellosis cases caused by the NTS is higher than those caused by typhoidal *Salmonella*. Hence, it is imperative to have a consistent record of NTS salmonellosis to estimate the actual burden caused by NTS *Salmonella* in Malaysia. It is noteworthy to know that *Salmonella* has resulted in food poisoning outbreaks and mortality, with *S.* Weltevreden and *S*. Typhimurium identified as the main causative agents (Abdul-Rahman *et al*., 2022; Ab Karim *et al*., 2014; Astro Awani, 2014). This highlights that the NTS *Salmonella* contribute to the overall burden of salmonellosis in Malaysia.

Several outbreaks of *S.* Weltevreden were also reported in other countries. These include cases linked to the consumption of *panipuri* from a street vendor in India (Chowdhury *et al*., 2024), frozen cooked shrimp in the US (FDA, 2021), and a community gastroenteritis outbreak in Oman (Al-Maqbali *et al*., 2021). However, none of these outbreaks resulted in fatal cases. Outbreaks caused by *S*. Typhimurium were also reported in the United States, associated with the consumption of contaminated cucumbers (CDC, 2025) and fresh basil (CDC, 2024). Denmark also recorded several outbreaks linked to the consumption of ground beef (Food Safety News, 2024). There were no deaths reported in these outbreaks. However, a study reported that *S*. Typhimurium was linked to patient death following the consumption of contaminated meat in Argentina (Food Safety News, 2023).

In line with global trends, the most frequently isolated *Salmonella* strains in Malaysia are *S*. Enteritidis and *S*. Typhimurium. These two strains have been detected and isolated in both food items and non-food items. Three *Salmonella* serovars, namely *S*. Typhi, *S*. Typhimurium and *S*. Weltevreden were the bacteria responsible for the *Salmonella* outbreak and deaths in Malaysia for the past 20 years. Interestingly, these same three serovars were also the most common serovars isolated in human cases between 1973 and 1982 (Jegathesan, 1984), suggesting their continued presence and circulation in Malaysia. Neighbouring countries such as Singapore and Thailand have also frequently reported the isolation of *S*. Weltevreden in humans (Bangtrakulnonth *et al*., 2004; Hounmanou *et al*., 2020).

In addition to *S*. Typhimurium and *S*. Weltevreden, other *Salmonella* serovars such as *S*. Albany, *S*. Braenderup, *S*. Bovismorbificans, *S*. Corvallis, *S*. Enteritidis, *S*. Matopeni, *S*. Muenchen, *S*. Newport, *S*. Paratyphi B var. Java, *S*. Richmond, *S*. Stanley, and *S*. Typhi have also been detected in both human and non-human samples in Malaysia. Notably, *S*. Typhimurium and *S*. Corvallis were present across all sample groups identified in this review, indicating their ability to contaminate a wide range of sources. The detection of similar *Salmonella* serovars in both human and non-human sources suggests potential transmission pathways from non-food or environmental sources to food, ultimately leading to human infection. Additionally, several *Salmonella* serovars were found to be unique to specific sample groups. However, it remains unclear whether these serovars are truly source-specific or simply reflect limitations in sampling coverage and study design.

Similar to global trends, *Salmonella* strains isolated in Malaysia also exhibit resistance to a wide range of antimicrobial agents. Several studies conducted in Malaysia have reported that *Salmonella* isolates show high levels of resistance to erythromycin, vancomycin and penicillin (Adzitey *et al*., 2012; Ibrahim *et al*., 2021; Ismail *et al*., 2024; Sukri *et al*., 2021; Thung *et al*., 2016; Thung *et al*., 2018). Notably, *Salmonella* isolates were resistant (87.4% – 100%) to these antibiotics in all studies that tested them. In addition, several systematic reviews and meta-analyses have consistently reported the resistance of *Salmonella* strains to erythromycin across different regions. In the Middle East, NTS strains isolated from both humans and food-producing animals showed high resistance rates (52% – 100%) to erythromycin, amoxicillin, tetracycline, ampicillin, amoxicillin/clavulanic acid, and cefotaxime (Abukhattab *et al*., 2022). Interestingly, consistent with the findings of the present review, *Salmonella* strains from the Middle East also exhibited 100% resistance to erythromycin. In South Africa, *Salmonella* isolates obtained from environment, animal, and human sources were highly resistant to sulphonamides, enrofloxacin, erythromycin, oxytetracycline, imipenem, tetracycline, and trimethoprim (52.2% – 92.0%) (Ramatla *et al*., 2021). In Burkina Faso, NTS isolated from human, environmental, animal, and food samples, also demonstrated high resistance (54.65% – 98.3%) to erythromycin, amoxicillin, cefixime, and cephalothin (Traore *et al*., 2024). Another systematic review and meta-analysis study on

Salmonella isolated from retail fresh fruit and vegetables across multiple geographical locations also found that these *Salmonella* isolates were resistant to erythromycin (60.70%) (Ma *et al*., 2024). These findings show that *Salmonella* strains, both in Malaysia and globally, commonly exhibit resistance to erythromycin, highlighting the urgent need for continuous antimicrobial resistance surveillance of *Salmonella* isolates and supporting the recommendation that erythromycin should not be used for the treatment of salmonellosis. Erythromycin is a macrolide antibiotic whose primarily mode of action is the inhibition of bacterial protein synthesis. Although the specific resistance mechanisms of *Salmonella* to erythromycin are not fully understood, resistance may arise through one or a combination of mechanisms, including active efflux systems, ribosomal target modifications, and enzymatic inactivation (Punchihewage-Don *et al*., 2024).

In Southeast Asia (Bangladesh, India, Pakistan, Nepal, Bhutan, Sri Lanka), the majority of *Salmonella* were found to be resistant to nalidixic acid and tetracycline (Talukder *et al*., 2023). In Iran, *S*. Typhimurium exhibited high resistance to piperacillin (79%) and tetracycline (60%), but showed no resistance to cefixime and ceftriaxone (Narimisa *et al*., 2024). A retrospective study conducted in the Campania Region of Italy found that nearly all *Salmonella* strains isolated from humans were resistant to azithromycin (99.4%) (Peruzy *et al*., 2025). In Ethiopia, *Salmonella* strains isolated from poultry farms were highly resistant (>50%) to tetracycline and oxytetracycline (Basazinew *et al*., 2025).

Despite of the high resistance of *Salmonella* isolates to some antibiotics in this present review, some antibiotics are still effective towards *Salmonella* isolates. Eight studies (Adzitey *et al*., 2012; Choe *et al*., 2011; Ibrahim *et al*., 2021; Kuan *et al*., 2017; Najwa *et al*., 2015; Tan *et al*., 2019; Thung *et al*., 2016; Thung *et al*., 2018) showed that *Salmonella* isolates were fully susceptible to gentamicin. This observation was also seen in other study in Ethiopia in which the *Salmonella* isolates exhibited low resistance to gentamicin (<6%) (Basazinew *et al*., 2025). *Salmonella* isolates in Malaysia were also fully susceptible to other antibiotics, such as piperacillin/tazobactam, imipenem and colistin sulphate which also reported in other countries, including South India (Srividhya *et al*., 2025) and Poland (Pławińska-Czarnak *et al*., 2022). However, studies from South and West Africa have reported high levels of resistance among *Salmonella* isolates from poultry products, with resistance rates ranging from 72.6% – 93.75% (Ramatla *et al*., 2021; Sacko *et al*., 2023).

The findings of this review demonstrate that *Salmonella* contamination in Malaysia originates from a wide range of sources. The detection of *Salmonella* in aquaculture products and environments, poultry products and environments, plant-based foods, and other less common sources such as flies, snakes, and dogs indicates that humans may be exposed to infection through multiple transmission routes. Therefore, the implementation of a One Health approach that emphasizes the integrated management of human, animal, and environmental health is critical for the prevention and control of salmonellosis. As *Salmonella* circulates across multiple reservoirs and transmission pathways, a coordinated, multisectoral strategy is essential to effectively reduce the risk of infection.

In addition, the findings of this review, together with evidence from studies conducted in other countries, suggest that despite growing concerns regarding antimicrobial resistance, certain antibiotics remain highly effective against *Salmonella* strains. Nevertheless, continuous surveillance and the prudent use of these antibiotics are crucial to preserve their therapeutic efficacy.

CONCLUSION

Salmonellosis remains a recurring public health concern in Malaysia, with food-related outbreaks posing significant risks. While cases related to foodborne illness and typhoid/paratyphoid are consistently recorded, the true burden of salmonellosis is difficult to ascertain due to the lack of comprehensive data on NTS salmonellosis infections. Hence, keeping a track record of salmonellosis cases caused by NTS is crucial to accurately estimate the disease burden and improve management strategies. In Malaysia, *Salmonella* was detected in a wide range of sources, including foods, surfaces and humans. A number of serovars were identified in which several serovars were isolated in both human and non-human samples. To better understand the extent of *Salmonella* contamination in Malaysia, more studies are still needed to be conducted across diverse sources, settings and geographic regions. In line with global trends, *Salmonella* isolates in Malaysia exhibit varied susceptibility pattern to antibiotics, with notable resistance to erythromycin penicillin. Continuous surveillance on the susceptibility of *Salmonella* against antibiotics is critical for the effective treatment of salmonellosis and for guiding the prudent use of antibiotics.

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