Infection and Drug Resistance

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REVIEW

A Systematic review on Prevalence, Serotypes and Antibiotic resistance of *Salmonella* in Ethiopia, 2010–2022

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Background: In Ethiopia, salmonellosis is one of the most common zoonotic and foodborne illnesses. Ethiopia continues to be at risk for its fast-expanding medication resistance. For the development of preventative and control methods, summarized knowledge regarding salmonellosis is necessary. Determining a thorough evaluation of the prevalence, serotypes, and antibiotic resistance of *Salmonella* in humans and animals from January 1, 2010, to December 30, 2022, in Ethiopia was our goal.
Methods: To find *Salmonella* related articles that published in English, we used the Google Scholar and PubMed search engines. Three researchers conducted the eligible studies using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, making sure to include the necessary keywords. If studies were duplicates, incomplete publications, or reported without an antimicrobial test were excluded. Excel 2013 was used to calculate frequencies and tabulate data.
Results: There were a total of 43 investigations from food handlers, diarrhoeic patients, and animals. The prevalence rates ranged from 1% to 10% and 1% to 13% among food handlers and diarrhoea patients, respectively. The highest prevalence was among pigs (41.6%). S. Anatum in animals and S. Typhimurium in people were the predominant serotypes. Amoxicillin and ampicillin were claimed to be 100% resistant in human studies. The highest recorded resistances for ceftriaxone and ciprofloxacin were 16.7% and 100%, respectively. Animal studies revealed that *Salmonella* resistances to ampicillin, streptomycin and tetracycline were 100%, 90%, 86.4%, respectively. S. Kentucky showed complete resistance to tetracycline, ampicillin, gentamicin, ciprofloxacin, and streptomycin.
Conclusion: The prevalence of *Salmonella* among asymptomatic food handlers, diarrheal patients and animals were high in Ethiopia. S. Typhimurium that have the zoonotic importance was presented predominantly in human study. High levels of resistances were showed to tetracycline, ampicillin and streptomycin in animal studies. Salmonellosis prevention and control techniques should be strengthened.
Keywords: antibiotic resistance, prevalence, systematic review, serotypes, *Salmonella*, Ethiopia

Introduction

Salmonellosis continues to be a serious global public health issue, particularly in developing nations.[1,2] One-fourth of 550 million diarrheic people worldwide are thought to contract *Salmonella* each year as a result of eating contaminated food.[3] Human typhoid fever is caused by Salmonella Typhi and Salmonella Paratyphi.[4] Some *Salmonella* are specific to animal species although others have wide variety of animals, in addition to humans, such as Salmonella Typhimurium and Salmonella Enteritidis.[5]

Red meat, carcasses, slaughterhouse equipment, and utensils can all get contaminated by the mesenteric lymph nodes and faeces of sick cattle, swine, sheep, or reservoir animals.[6–10] As a result, eating raw or undercooked meat or eggs results in human infection.[11] Salmonella infections can also be carried by human and animal faeces, which can contaminate crops.[12] In addition, hospitalization has been implicated as a source of invasive non-typhoidal

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Salmonella.[13] Salmonella infections can lead to outbreaks of human salmonellosis and a variety of clinical symptoms, such as mild gastroenteritis, bacteremia, and extra-intestinal localized infections affecting numerous organs.[1]

One of the present and expanding global risks to public health is Salmonella drug resistance. According to a study from Mexico, non-typhoidal Salmonella had a resistance range of 16.9% to 40.3% to the antibiotics trimethoprim-sulfamethoxazole, amoxicillin-clavulanic acid, chloramphenicol, and tetracycline.[14] Similar to this, the *Salmonella* serotypes found in food and people in Italy were resistant to tetracycline (48%) and ampicillin (45%),[15] and from China, the NTS resistance pattern to ceftriaxone was 37%.[16] Additionally, 36,000 and 33,000 cases of salmonella infections resistant to ciprofloxacin and ceftriaxone, respectively, were reported annually from the United States.[17] Salmonella serotypes resistant to ceftriaxone have also been reported in Kenya.[18]

According to the prior data, an article on *Salmonella* in Ethiopia had been published since 1985,[19] and in 1994, Salmonella Newport had been discovered in suspected food poisoning cases among students and food handlers in Gondar, Ethiopia.[20] From various regions in Ethiopia, a lot of papers about *Salmonella* have been published. These researches looked at the frequency of different Salmonella species, serotypes, and medication resistance patterns in people, animals, and vegetables. Numerous *Salmonella* isolates with high levels of antibiotic resistance have been discovered.[21–24]

Ethiopia had vast livestock animals in Africa, and living alongside people is prevalent there.[25] This may cause the spread of zoonotic illnesses like non-typhoidal salmonella[26] as individuals in Ethiopia do not fully comprehend how zoonoses, such as *Salmonella* are spreading.[27] As a result, large number of vulnerable individuals like malnourished children may be exposed to the invasive form of non-typhoidal *Salmonella*.[28,29]

Despite the fragmented local studies about *Salmonella* that have been reported from various regions of Ethiopia, concise information from a systematic review is more helpful for scientific users to identify gaps for additional studies and for policymakers to develop prevention and control strategies based on the scientific information provided. Thus, we sought to conduct a systematic evaluation of the prevalence, serotypes, and antibiotic resistance of Salmonella in people, animals, and their products in Ethiopia from January 1, 2010, to December 30, 2022.

Methods

Literature Search

To find English-language publications concerning *Salmonella* that had already been published, we used the Google Scholar and PubMed search engines. Keywords like "prevalence", "incidence", "Salmonella", "Salmonella serotypes", "food handlers", "diarrheic patients", "antibiotic susceptibility", "antimicrobial susceptibility", "antibiotic resistance", "antimicrobial resistance", "animals", "humans", and "Ethiopia" were used to search the included studies.

The Inclusion and Exclusion Standards

Three researchers independently conducted the eligible studies using the PRISMA[30] checklist to make sure all pertinent data was included. If a study met the requirements listed below, it was qualified for the systematic review: *Salmonella* resistance and prevalence in animals and humans are mentioned in the purpose, which is also stated in the design, sample size, description of the microbiological procedures, and number of isolates. The study was published in English. Studies were disregarded if they were duplicates, partial papers, or reported Salmonella without an antimicrobial test.

Obtaining and Analyzing Data

From each examined paper, the names of the authors, the publication year, the kind of media, the study setting, the sampling techniques, the study populations, the type of specimens, the sample size, the number of positive isolates, the antimicrobial susceptibility tests, and the list of serotypes (if any) were taken. Using Excel 2013, frequencies and percentages were examined.

Results

Between January 1, 2010, and December 30, 2022, the search engines Google Scholar and PubMed turned up a total of 207 published papers; 100 of those articles were disregarded from additional examination owing to duplication. After reviewing the 107 research titles and abstracts, it was determined that 52 did not meet the requirements for inclusion.

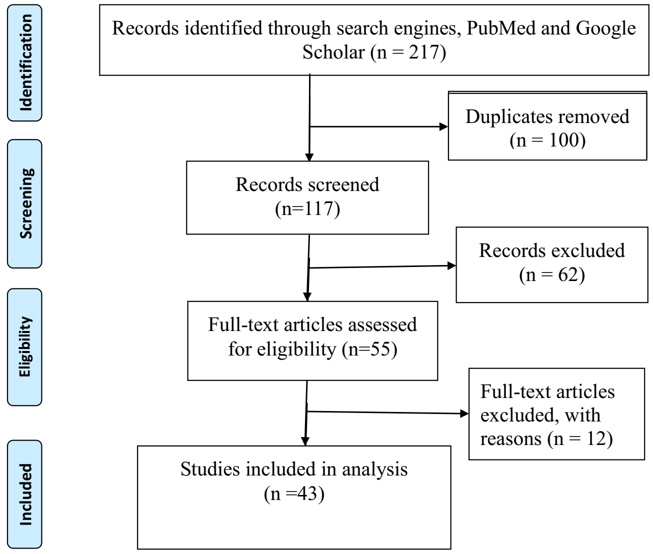

Figure 1 Flow Diagram for Selection of Eligible Studies. Adapted from Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097. Creative Commons.[30]

Only 55 articles that met the requirements for eligibility were given a second evaluation, and 12 of them were disqualified for various reasons. Figure 1 shows that our systematic review only comprised 43 papers.

Characteristics of Studies on *Salmonella* among Asymptomatic Food Handlers and Diarrhoea Patients

Of the 43 eligible studies that were conducted, 28 were asymptomatic food handlers from the community and diarrhoeic patients from public health facilities. While 13 types of research involved asymptomatic food handlers working in university and community cafeterias, 15 studies involved children and adults with diarrhoea. The only clinical specimens reported in any of the investigations for *Salmonella* isolation were faeces. The most frequently employed media were Xylose Lysine Deoxycholate, Deoxycholate Citrate Agar, MacConkey Agar, and Salmonella Shigella Agar. According to Table 1, convenience sampling was used in 19 of the investigations, while simple random sampling was used in the other nine.

Salmonella Prevalence in Asymptomatic Food Handlers and Diarrheal Patients

Salmonella prevalence in asymptomatic food handlers (n=13) ranges from 1% to 10%, but it ranges from 1% to 13% in diarrhoeic patients (n=15). More than three-fourths of the reports among asymptomatic food workers had prevalence rates that were less than 5%. On the other hand, in more than two-thirds of the cases, including diarrheal patients, the prevalence rates were 5% or higher as shown in Table 2.

Characteristics of Research on *Salmonella* in Animal-Related Samples

The specimens used to isolate *Salmonella* came from cattle, poultry, pigs, goats, and sheep. These included the contents of the caecum, mesenteric lymph nodes, liver, tongue, hide swabs, rumen, faeces, and cecum, as well as the contents of market eggs and market eggshells. All studies involving animals used the following essential pre-enrichment, enrichment, and selective media: buffered peptone water, brilliant green phenol red lactose sucrose, xylose lysine deoxycholate, MacConkey agar, brilliant green agar, xylose lysine territory 4, selenite cysteine broth, Rappaport-Vassiliadis, and Tetrathionate broth.

Salmonella is present in all of the animal-related specimens, with prevalence ranging from 3.1% in poultry to 29.1% in pig mesenteric lymph nodes. Table 3 lists the results of the investigations that examined the tissue and faeces of pigs, cattle, poultry, sheep, and goats.

Table 1 A Systematic Review of Characteristics of Asymptomatic Food Handlers and Public Health Facility Diarrheic Patients in Ethiopia, January 1, 2010, to December 30, 2022

Authors Name with Reference	Transport & Enrichment Media	Selective and Differential Media	Study Setting	Sampling Method	Study Population	Specimen
Food handlers						
Gebreyesus et al, 2014[31]	SFB	XLD	University	Convenience	Food handlers	Stool
Getie et al, 2019[32]	CTM and SCB	XLD and SSA	Community	SRS	Food handlers	Stool
Abera et al, 2010[33]	SFB	SSA	Community	SRS	Food handlers	Stool
Solomon et al, 2018[34]	SFB	XLD and BGA	Community	SRS	Food handlers	Stool
Awol et al, 2019[35]	CTM	XLD and MAC	Community	SRS	Food handlers	Stool
Yesigat et al, 2020[36]	CTM and SFB	XLD and MAC	Community	SRS	Food handlers	Stool
Aklilu et al, 2015[37]	SFB	XLD	University	SRS	Food handlers	Stool
Kifelew et al, 2014[38]	SCB	RVB, TTB and XLD	University	SRS	Food handlers	Stool
Getnet et al, 2014[39]	SFB	XLD	University	Convenience	Food handlers	Stool
Mengist et al, 2018[40]	RVB	TTB, XLD, BGA	University	Convenience	Food handlers	Stool
Tadesse et al, 2019[41]	CTM and SFB	XLD and DCA	Community	SRS	Street Food vendor	Stool
Mama and Alemu, 2016[42]	SFB	XLD and MAC	University	Convenience	Food handlers	Stool
Diriba et al, 2020[43]	CTM and SFB	XLD and DCA	University	SRS	Food handlers	Stool
Diarrheic patients						
Tosisa et al, 2020[44]	CTM and SFB	XLD, MAC	Healthfacility	Convenience	Diarrheic children	Stool
Abebe et al, 2018[45]	CTM and SFB	XLD, DCA	Healthfacility	Convenience	Diarrheic children	Stool
Getamesay et al, 2014[46]	CTM and SFB	XLD, DCA	Healthfacility	Convenience	Diarrheic children	Stool
Mamuye et al, 2015[47]	CTM	XLD, DCA, SSA	Healthfacility	Convenience	Diarrheic children	Stool
Mulu et al, 2017[48]	SFB	MAC, XLD	Healthfacility	Convenience	Diarrheic patients	Stool
Kebede et al, 2017[49]	SFB	XLD, MAC	Healthfacility	Convenience	Diarrheic patients	Stool
Amsalu et al, 2021[50]	CTM	MAC	Healthfacility	Convenience	Diarrheic patients	Stool
Beyene and Tasew, 2014[51]	CTM and SFB	XLD, DCA	Healthfacility	Convenience	Diarrheic children	Stool
Eguale et al, 2015[52]	RVB,	XLT 4	Healthfacility	Convenience	Diarrheic patients	Stool
Gebreegziabher, 2018[53]	SFB	MAC, XLD	Healthfacility	Convenience	Diarrheic children	Stool
Terfassa, 2018[54]	SFB	XLD, SSA	Healthfacility	Convenience	Diarrheic patients	Stool
Asefa et al, 2019[55]	SCB	HEA, SSA	Healthfacility	Convenience	Diarrheic children	Stool
Lamboro et al, 2016[56]	SFB	XLD	Healthfacility	Convenience	Diarrheic patients	Stool
Reda et al, 2011[57]	SFB	CTM, XLD, DCA	Healthfacility	Convenience	Diarrheic patients	Stool
Ameya et al, 2018[58]	Not use	XLD, MAC	Healthfacility	Convenience	Diarrheic children	Stool

Abbreviations: CTM, Cary Blair Transport media; DCA, Deoxycholate Citrate Agar; XLD, xylose Lysine Deoxycholate Agar; Selenite F broth; nr not reported; MAC, MacConkey agar; SSA, Salmonella Shigella agar; RVB, Rappaport-Vassiliadis; TTB, Tetrathionate broth; BGA, brilliant green; SRS, Simple Random sampling.

Table 2 A Systematic Review of the Prevalence of *Salmonella* Among Asymptomatic Food Handlers and Public Health Facilities Diarrheic Patients in Ethiopia from January 1, 2010, to December 30, 2022

Authors name with Reference	Sample size	Isolates	Percent
Food handlers			
Gebreyesus et al, 2014[31]	307	3	1
Getie et al, 2019[32]	257	3	1
Abera et al, 2010[33]	384	6	1.6
Solomon et al, 2018[34]	387	35	2
Awol et al, 2019[35]	236	5	2
Yesigat et al, 2020[36]	243	6	2
Aklilu et al, 2015[37]	172	6	3
Kifelew et al, 2014[38]	423	13	3
Getnet et al, 2014[39]	233	8	3.4
Mengist et al, 2018[40]	220	8	4
Tadesse et al, 2019[41]	218	13	6
Mama and Alemu, 2016[42]	345	24	7
Diriba et al, 2020[43]	220	21	10
Diarrheic patients			
Tosisa et al, 2020[44]	239	3	1
Abebe et al, 2018[45]	204	2	1
Getamesay et al, 2014[46]	158	4	3
Mamuye et al, 2015[47]	253	10	4
Mulu et al, 2017[48]	575	24	4
Kebede et al, 2017[49]	215	11	5
Amsalu et al, 2021[50]	150	8	5.3
Beyene and Tasew, 2014[51]	260	16	6
Eguale et al, 2015[52]	957	59	6.2
Gebreegziabher, 2018[53]	260	19	7
Terfassa, 2018[54]	422	30	7
Asefa et al, 2019[55]	422	29	7
Lamboro et al, 2016[56]	176	19	11
Reda et al, 2011[57]	244	28	11
Ameya et al, 2018[58]	167	21	13

Salmonella Antibiotic Resistance Among Food Handlers and Diarrheal Patients

A minimum of nine antibiotics were used to assess the resistance of Salmonella isolates. Amoxicillin, ampicillin, tetracycline, trimethoprim-sulfamethoxazole, chloramphenicol, nalidixic acid, gentamicin, ciprofloxacin, and ceftriaxone

Table 3 A Systematic Review of the Prevalence of *Salmonella* in Animals Associated Specimens in Ethiopia from January 1, 2010, to December 30, 2022

Authors Name with Reference	Pre-Enrichment	Enrichment & Selective Media	BT	SAT	Participant	Type of Samples	Sample Size	Isolates	%
Eguale et al, 2016[22]	BPW	RVB, BPLS, XLD	Yes	Yes	Pig	Caecal content, MLN	556	162	29.1
Dagnew et al, 2020[59]	BPW	RVB, XLD	Yes	Yes	Poultry	Cloacal and fecal content	718	22	3.1
Worku et al, 2022[60]	BPW	MAC, XLD	Yes	Nr	Cattle	Meat and swab	556	23	4.1
Tadesse et al, 2019[61]	BPW	SCB, BGA, XLD	Yes	Nr	Egg	Market egg and eggshell	166	7	4.2
Eguale T, 2018[62]	BPW	RVB, BGA, XLD	Yes	Nr	Poultry	Faecal	549	26	4.7
Alemu and Zewde, 2012[63]	BPW	SCB, XLD	Yes	Nr	Cattle	MLN, Intestinal, carcass	558	26	4.7
Mustefa and Gebreedhin, 2018[64]	BPW	RVB, TTB, XLT4	Yes	Nr	Cattle	Faecal, MLN	300	17	4.7
Alemu et al, 2022[65]	BPW	RVB, BPLS, XLD	Yes	Yes	Goats and sheep	Carcass & skin swabs	345	21	6
Wabeto et al, 2017[66]	BPW	RVB, BGA, XLD	Yes	Nr	Cattle	Carcass	896	56	6.3
Addis et al, 2011[67]	BPW	RVB, TTB, XLT4	Yes	Nr	Cow	Fecal and milk	390	21	7
Takele et al, 2018[68]	BPW	RVB, MAC, XLD	Yes	Nr	Cattle	Caecal and fecal	390	33	8.9
Mohammed and Dubie, 2022[69]	BPW	RV	Yes	Nr	Poultry	Cloacal swab	168	21	12.5
Sibhat et al, 2011[70]	BPW	RVB, BPLS, XLD	Yes	Yes	Cattle	Hide, rumen, caecal, MLN	400	64	16
Usmael et al, 2022[71]	BPW	SCB, BGA, XLD	Yes	Nr	Dog	Rectal swab samples	415	26	6.3
Belachew et al, 2021[72]	BPW	RV, SSA, XLD, BGA	Yes	Nr	Chicken	Cloacal &cecum	289	71	24.6

Abbreviations: Nr, Not reported; BPW, Buffered Peptone Water; BPLS, brilliant green phenol red lactose sucrose; XLD, Xylose Lysine Deoxycholate; MAC, MacConkey; BGA, Brilliant Green Agar; XLT4, Xylose Lysine Tergitol 4; SCB, Selenite Cysteine Broth; RVB, Rappaport-Vassiliadis; TTB, Tetrathionate broth; BT, Biochemical tests; SAT, Slide Agglutination Test; MLN, Mesenteric Lymph Node.

were on the lists of antibiotics taken from the studies that qualified. In six investigations for amoxicillin (two from food handlers and four from diarrhoea patients) and eight for ampicillin (four from food handlers and four from diarrhoea patients), all of the isolates displayed 100% resistance. Seven investigations (three in food handlers and four in diarrhoea patients) and eight (two in food handlers and six in diarrhoea patients), respectively, identified resistant isolates for ciprofloxacin and ceftriaxone. Although diarrhoeic patients appear to have relatively significant resistance, Table 4 shows that the highest reported ciprofloxacin and ceftriaxone resistance rates were 16.7% and 100%, respectively. Among all the asymptomatic food handlers and diarrheal patients tested for *Salmonella*, only one study was found eligible for serotyping. The leading serotype that reported from that study was S. Typhimurium, whereas single isolate of S. Concord showed 100% resistance to amoxicillin, ampicillin, tetracycline, gentamicin, sulfamethoxazole trimethoprim and ciprofloxacin as indicated in Table 4.

Table 4 A Systematic Review of Antibiotic Resistance of *Salmonella* Among Asymptomatic Food Handlers and Public Health Facility Diarrheic Patients in Ethiopia from January 1, 2010 to December 30, 2022

Authors name, Number of isolates and Reference	Antibiotics Resistance, n (%)								
	AMO	AMP	T	SXT	C	NA	CN	CIP	CRO
Food handlers									
Gebreyesus et al (n=3)[31]	ND	2 (66.7)	2 (66.7)	ND	3 (100)	ND	0	0	ND
Getie et al (n=3)[32]	1 (33.3)	0	2 (66.7)	1 (33.3)	0	0	1 (33.3)	0	0
Abera et al (n=6)[33]	ND	6 (100)	4 (66.7)	5 (83.3)	2 (33.3)	ND	2 (33.3)	ND	ND
Solomon et al (n=35)[34]	26 (74.3)	30 (85.7)	ND	24 (68.6)	9 (25.7)	15 (42.9)	ND	5 (14.3)	10 (28.6)
Awol et al (n=5)[35]	Nr	3 (60)	4 (80)	2 (40)	2 (40)	1 (20)	ND	0	0
Yesigat et al (n=6)[36]	ND	6 (100)	5 (83.3)	1 (16.7)	0	ND	ND	0	ND
Aklilu et al (n=6)[37]	6 (100)	6 (100)	0	ND	ND	ND	0	0	ND
Kifelew et al (n=13)[38]	6 (46.2)	7 (53.8)	6 (42.3)	2 (15.4)	ND	2 (15.4)	0	ND	0
Getnet et al (n=8)[39]	ND	7 (87.5)	1 (12.5)	1 (12.5)	1 (12.5)	Nr	0	1 (12.5)	0
Mengist et al (n=8)[40]	ND	8 (100)	5 (83.3)	3 (37.5)	2 (25)	ND	0	0	ND
Tadesse et al (n=13)[41]	12 (92.3)	12 (92.3)	10 (77)	2 (15.4)	1 (7.7)	2 (15.4)	2 (15.4)	0	0
Mama and Alemu (n=24)[42]	24 (100)	ND	ND	0	0	ND	0	ND	0
Diriba et al (n=21)[43]	15 (71.4)	17 (81)	ND	10 (47.6)	15 (71)	ND	ND	5 (23.8)	3 (100)
Diarrheic patients									
Tosisa et al (n=3)[44]	0	3 (100)	2 (66.7)	2 (66.7)	1 (33.3)	0	0	0	ND
Abebe et al (n=2)[45]	ND	2 (100)	ND	1 (50)	0	0	2 (100)	0	0
Getamesay et al (n=4)[46]	0	0	0	0	0	1 (25)	0	0	4 (100)
Mamuye et al (n=10)[47]	8 (80)	8 (80)	ND	6 (60)	4 (40)	2 (20)	0	0	0
Mulu et al (n=24)[48]	8 (33.3)	22 (91.7)	0	8 (33.3)	4 (16.7)	ND	ND	4 (16.7)	9 (37.5)
Kebede et al (n=11)[49]	ND	ND	7 (63.7)	8 (72.7)	8 (72.7)	1 (9)	1 (9)	1 (9)	1 (9)
Amsalu et al (n=8)[50]	ND	ND	7 (87.5)	7 (87.5)	4 (50)	3 (37.5)	2 (25)	1 (12.5)	2 (25)
Beyene and Tasew (n=16)[51]	16 (100)	10 (62.5)	ND	5 (31.3)	3 (18.8)	2 (12.5)	0	0	0
Eguale et al, 2015[52]									
• S. Typhimurium (n=27)	4 (14.8)	6 (22.2)	3 (11.1)	1 (3.7)	1 (3.7)	0 (0)	0 (0)	0 (0)	1 (3.7)
• S. Newport (n=2)	1 (50)	1 (50)	0 (0)	1 (50)	0 (0)	1 (50)	0 (0)	0 (0)	0 (0)
• S. Virchow (n=21)	1 (4.8)	1 (4.8)	3 (14.3)	0 (0)	0 (0)	10 (47.6)	0 (0)	0 (0)	0 (0)
• S. Kottbus (n=7)	0 (0)	0 (0)	1 (14.3)	0 (0)	1 (14.3)	0 (0)	0 (0)	1 (14.3)	0 (0)
• S. Enteritidis (n=1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
• S. Braenderup (n=1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
• S. Concord (n=1)	1 (100)	1 (100)	1 (100)	1 (100)	0 (0)	0 (0)	1 (100)	1 (100)	0 (0)
• S. Miami (n=3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

(*Continued*)

Table 4 (Continued).

Authors name, Number of isolates and Reference	Antibiotics Resistance, n (%)								
	AMO	**AMP**	**T**	**SXT**	**C**	**NA**	**CN**	**CIP**	**CRO**
• S. Kentucky (n=2)	2 (100)	2 (100)	2 (100)	2 (100)	0 (0)	2 (100)	2 (100)	2 (100)	0 (0)
Gebregziabher et al (n=19)[53]	ND	17 (89.5)	17 (89.5)	11 (57.9)	15 (78.9)	6 (31.6)	3 (15.8)	0	2 (10.5)
Terfassa et al (n=30)[54]	27 (90)	ND	ND	ND	2 (6.6)	1 (3.3)	3 (10)	2 (6.7)	1 (3.3)
Asefa et al (n=29)[55]	29 (100)	ND	23 (79)	ND	9 (31)	ND	ND	0	0
Lamboro et al (n=19)[56]	ND	19 (100)	9 (47.6)	1 (5.3)	1 (5.3)	5 (26.3)	1 (5.3)	0	ND
Reda et al (28)[57]	28 (100)	28 (100)	20 (71.4)	ND	18 (64.3)	ND	1 (3.6)	ND	ND
Ameya et al (21)[58]	21 (100)	ND	ND	8 (38.1)	9 (42.9)	ND	4 (19)	0	ND

Abbreviations: AMP, Ampicillin; AMO, Amoxicillin; SXT, sulfamethoxazole-trimethoprim; NA, Nalidixic acid; CRO, Ceftriaxone; CIP, Ciprofloxacin; C, Chloramphenicol; CN, Gentamicin; T, Tetracycline; ND, Not Done.

Animal *Salmonella* with Antibiotic Resistance

As shown in Table 5, all Salmonella isolates from investigations involving animal-related samples were resistant to ampicillin, 90% to streptomycin, 66.7% to chloramphenicol, 86.4% to tetracycline, 35.2% to ciprofloxacin, 29.4% to gentamicin, and 23.2% to ceftriaxone. When it comes to salmonella serotypes' resistance to antibiotics, the ampicillin,

Table 5 A Systematic Review of Antibiotic Resistance of *Salmonella* in Species and Serotype Level in Animals Related Specimens in Ethiopia from January 1, 2010 to December 30, 2022

Authors Name, Number of Isolates and Reference	Antibiotics Resistance, n (%)						
	AMP	**GEN**	**CIP**	**C**	**S**	**T**	**CRO**
Eguale et al, 2016[22]							
• S. Kentucky (n=5)	5 (100)	5 (100)	5 (100)	0 (0)	5 (100)	5 (100)	0 (0)
• S. Virchow (n=5)	3 (60)	1 (20)	0 (0)	0 (0)	2 (40)	1 (20)	0 (0)
• S. Saintpaul (n=6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
• S. Typhimurium (n=7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
• S. Dublin (n=3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Dagnew et al, 2020 (n=22)[59]	0 (0)	0 (0)	0 (0)	0 (0)	20 (90.1)	19 (86.4)	0 (0)
Worku et al, 2022 (n=23)[60]	ND	0 (0)	ND	ND	ND	6 (26)	0 (0)
Eguale 2018[62]							
• S. Saintpaul (n=20)	9 (45)	0 (0)	0 (0)	10 (50)	18 (90)	4 (20)	5 (25)
• S. Typhimurium (n=3)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)	1 (33.3)	1 (33.3)
• S. Kentucky (n=2)	2 (100)	2 (100)	2 (100)	1 (50)	2 (100)	2 (100)	0 (0)
Alemu and Zewde, 2012 (n=21)[63]	1 (4.8)	0 (0)	1 (4.8)	0 (0)	ND	2 (9.5)	0 (0)
Mustefa et al, (n=17)[64]	17 (100)	5 (29.4)	6 (35.2)	0 (0)	7 (41.1)	ND	0 (0)
Wabeto et al, 2017 (n=56)[66]	26 (46.4)	7 (12.5)	4 (7.1)	29 (51.8)	37 (66)	47 (83.9)	13 (23.2)

(*Continued*)

Table 5 (Continued).

Authors Name, Number of Isolates and Reference	Antibiotics Resistance, n (%)						
	AMP	**GEN**	**CIP**	**C**	**S**	**T**	**CRO**
Addis et al, 2011 (n=21)[67]	21 (100)	4 (19)	0 (0)	2 (9.5)	16 (76.2)	7 (33.3)	ND
Takele et al, 2018 (n=42)[68]	13 (31)	3 (7)	0 (0)	3 (7)	10 (23.8)	10 (23.8)	0 (0)
Mohammed and Gebremedhin (n=21)[69]	7 (33.3)	(4.8)	(4.8)	7 (33.3)	13 (61.9)	15 (71)	ND
Sibhat et al, 2011[70]							
• S. Typhimurium (n=1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
• S. Newport (n=13)	0 (0)	0 (0)	0 (0)	0 (0)	4 (66.7)	0 (0)	0 (0)
• S. Anatum (n=39)	2 (66.7)	0 (0)	0 (0)	0 (0)	3 (100)	2 (66.7)	0 (0)
Usmael et al, 2022[71]	11 (41.7)	0 (0)	ND	ND	ND	9 (21.2)	ND
Belachew et al, 20 (n=71)[72]	38 (53.5)	7 (10)	ND	47 (66.7)	43 (60.6)	56 (79)	ND

Abbreviations: AMP, Ampicillin; GEN, Gentamycin; CIP, ciprofloxacin; CAF, Chloramphenicol; S, streptomycin; TTC, tetracycline; CRO, ceftriaxone; ND, Not done.

gentamicin, ciprofloxacin, streptomycin, and tetracycline resistance in S. Kentucky was 100% although the leading isolates of salmonella serotypes reported from the researches were S. Anatum, S. Saintpaul, S. Newport, and S. Typhimurium.

Discussion

One of the main contributors to foodborne and zoonotic diseases in underdeveloped nations is *Salmonella*.[1,2] It is one of Ethiopia's top seven priority zoonotic diseases[73] and a significant source of foodborne pathogens.[74]

Salmonella prevalence among asymptomatic food handlers ranges from 1% to 10%, which was consistent with research from Pakistan (9.1%).[75] Similar to this, the prevalence of *Salmonella* among individuals who have diarrhoea ranges from 1% to 13%. However, one instance at a hospital suggests that there are 30 other cases in the community who are unable to visit hospitals for a variety of reasons.[76]

The prevalence rates of *Salmonella* in animal-related sources range from 3.1% in poultry to 29.4% in pigs, followed by cloacal and cecal content of chicken (24.6%) which is consistent with studies from Burkina Faso,[77,78] Italy,[79] Kenya,[80] South Africa,[81] and Uganda,[82] Vietnam,[83] China,[84] and Louisiana.[85]

S. Typhimurium were reported in all of the legible studies for serotyping which was also reported from Gambia,[86] Mali,[87] India,[88] Mexico,[89] and China.[90] According to reports from sub-Saharan African nations, S. Typhimurium and S. Enteritidis are invasive forms of NTS, especially among susceptible people, such as those with HIV, malnourished children, and in malaria areas.[77,91] It is possible that the existence of such *Salmonella* germs in cattle, poultry, pigs, and other animal sources is regarded as a potential source of contamination in humans and maybe the main risk factor for *Salmonella* outbreaks in humans.[8]

Six human studies found that every isolate of *Salmonella* tested had a 100% amoxicillin resistance rate, which is consistent with an Ethiopian study.[24] Ciprofloxacin-resistant isolates were detected in seven human studies which is similar to studies from China,[92] and Mexico.[93]

Salmonella isolates from two investigations had 100% ampicillin resistance, which was higher than the prior study in Japan.[6] However, the streptomycin resistance patterns were consistent with earlier Japanese studies.[6] For ciprofloxacin, gentamicin, and ceftriaxone, similar animal specimens showed at least 25% resistance. S. Kentucky showed 100% resistance to ampicillin, gentamicin, ciprofloxacin, streptomycin, and tetracycline out of the known serotypes from our systematic evaluation.

The results of our systematic review are very beneficial in helping people understand important information concerning *Salmonella*. We were unable to include *Salmonella* in food, fruits, or vegetables because of limited data. Additionally, no studies that were included in this systematic review performed molecular characterization of *Salmonella* and its resistance genes or invasive non-typhoidal salmonella among malnourished children because of no studies related.

Conclusions

The prevalence of *Salmonella* in animals, diarrhoeal patients, and asymptomatic food handlers was high. The prevalence of *Salmonella* among asymptomatic food handlers and diarrheal patients was nearly similar. S. Typhimurium that has the zoonotic nature was recovered from human and animal studies. Studies on animals revealed high levels of resistance to tetracycline, ampicillin, and streptomycin. Circulating of *Salmonella* in the community in Ethiopia is a homework for academic and non-academic researchers to overcome fear of future outbreaks. National and international organizations should work on strengthening the prevention and control of salmonellosis. Due to Ethiopia's high prevalence of underweight children and the prevalence of those who are susceptible to the invasive form of NTS, invasive non-typhoidal salmonella among malnourished children should be examined.

Disclosure

The authors report no conflicts of interest in this work.

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