Prevalence and antimicrobial resistance of animal Salmonellosis in Ethiopia

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Research article

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Abstract

Background Salmonellosis remained the global public health problems of animals and humans. Consumption of animal food from infected animals or from the contamination of carcasses such as cattle, swine, and sheep and poultry are the main sources of non-Typhoidal Salmonella and the leading cause of zoonotic foodborne diseases. The eligibility criteria of this study has included publication in English, cross-sectional study, samples of food animal origin, antimicrobial sensitivity test methods. Google Scholar and PubMed have used to search the prevalence, incidence, distribution, antimicrobial resistance, animals and humans. Author, study area, study period, sample sources, number of animals, number of samples, positive isolates were used as search strategy.

Results A total of 8.4% (564/6721) animal salmonellosis were identified from 11 studies in Ethiopia. The source of samples were pigs, cattle, poultry, and eggs. Five studies were selected for the analysis of prevalence and drug resistance of animal salmonellosis whereas six were found eligible for analysis of animal salmonellosis in serotype level and twenty nine serotypes were extracted having 354 isolates. Of the total 147(6.1%) isolates in five studies, ampicillin, streptomycin and tetracycline were resistant to 89 (60.5%), 70 (47.6%) and 64(43.5%) respectively. The resistant profile for ceftriaxone, gentamicin and ciprofloxacin were 20 (13.6%), 21 (12.9%) and 10 (6.8%), respectively. Twelve serotypes having 204 isolates have showed antimicrobial resistance. Six serotypes had multidrug resistance comprising 120 isolates. The predominant serotype that showed MDR (to three antibiotics) was S. Hadar 81 (67.5%) followed by S. Kentucky 22(18.3%).

Conclusion The overall prevalence of animal salmonellosis in Ethiopia was 8.4% (564/6721). The source of samples for the assessment of the prevalence of animal salmonellosis in Ethiopia were pigs, cattle, poultry, and eggs. Of the total 147(6.1%) isolates in five studies, ampicillin, streptomycin and tetracycline were resistant to 89 (60.5%), 70 (47.6%) and 64(43.5%), respectively. A total of 29 serotypes comprising 354 isolates were revealed from six studies. Twelve serotypes having 204 isolates were showed antimicrobial resistance. Six serotypes showed multidrug resistance and the predominant serotype that showed MDR was S. Hadar 81 (67.5%) followed by S. Kentucky 22(18.3%)

Background

Overview of Salmonellosis

Salmonellae seems to be familiarized in the digestive system of humans and animals. Hence, the presence of Salmonellae in water, food, and environment is elucidated by fecal contamination (1). More than 2500 serotypes/serovars of Salmonellae has been reported (2) and of which 1500 subspecies are associated with human and animal diseases (3) although there is a variation in nature and rigidity among different animals and affected by age, dose, strain virulence, host species, immune status of the host and geographic regions (4). The most clinically important species of Salmonellae is *Salmonella enterica* subspecies *enterica* (2). *Salmonella enterica* subspecies *enterica* serotype Typhi and para Typhi are highly adapted to human and causes Typhoid fever and para Typhoid fever (5) whereas there are serotypes of *Salmonella* that adapted animals such as *S. Choleraesuis* in pigs, *S. Dublin* in cattle, *S. Abortusovis* in sheep and *S. Gallinarum* in poultry; however, some serotypes like *S. Typhimurium* affect human and a wide range of animals (6). Consumption of raw/undercooked meat, raw/undercooked eggs and not cleaning chopping board when using it for raw meat and other foods are the contributing factors for the transmission of human Salmonellosis (7).

Nontyphoidal *Salmonella* cause bacteremia in the globe particularly in Africa and the annual burden is estimated to be 3.4 million (8) even though the majority of human NTS infection in developed countries are associated with enterocolitis and this is believed to arise through the food chain (9). Non-Typhoidal *Salmonella* is the leading cause of zoonotic foodborne diseases that are linked with the consumption of infected animals used in food production or from contamination of the carcasses (10) such as cattle, swine, and sheep (11). Animals are the main reservoirs of human Salmonellosis (12, 13) though vegetable foods contaminated by animal products and human excreta have been implicated as the automobile of human salmonellosis (14). *Salmonellae* in the infected animals' mesenteric lymph nodes and feces can contribute as a

source for the contamination of red meat and other edible parts of the carcasses (14, 15) and also by the contaminated abattoir equipment and utensils (15, 16).

The public health problem of Salmonella is not only by its infection but also by its drug resistance and economic impacts (17). The highest number of illnesses, hospitalizations, and deaths associated with foodborne illness are due to non-Typhoidal Salmonella (18). About 100,000 infections are associated with drug-resistant Salmonella such as annual infections due to ceftriaxone and ciprofloxacin in the United States of America, are 36,000 and 33,000 respectively (17).

Prevalence of Animal Salmonellosis

The prevalence of animal Salmonellosis in chicken meat from Vietnam (15), Russia (18), Iran (16), in chicken meat, beef and pork from South Korea (19) and from poultry in China (21) were 128 (48.9%), 220 (31.5%), 111 (19.8%), 17 (13%), 601 (52.2%), respectively.

Twelve (1.1%) Salmonella species were isolated from 1,108 meat samples in New Zealand with a proportion of 3% in chicken, 1.3% in lamb and mutton, 0.5% in beef, and 0% in pork (22) and Salmonella was isolated from 22% (31 of 141) of the conventional and 20.8% (11 of 53) of the organic chicken samples in Louisiana (23). Of the total 225 retail meat products conducted in Turkey, 50 (22.2%) were positive for Salmonella with 22 (29.3%) poultry meat (n = 75), 16 (21.3%) ground beef (n = 75), and 12 (16%) beef (n = 75) (20%) (24). Salmonella strains were isolated from 271 (27%) carcass samples in Colombia (25).

Of the examined poultry meat samples in Egypt, 10 (10%) Salmonella species were isolated (26). Salmonella was isolated from 383 (53%) of the total of 729 fecal samples including 159 (52%) of the cattle feces, 192 (55%) of the chicken feces, 8 (16%) of the swine feces and 24 (96%) of the hedgehog feces in Burkinafaso (27). Of the 435 retailed beef and related meat products tested in a study conducted in Nigeria, 10 (2.3%) Salmonella species isolates were revealed (28).

A total 624 and 600 samples examined from sheep and goats in Ethiopia and 18 (2.9%) and 4 (0.7%) were Salmonella positive (29), respectively and of the 156 chicken eggs examined in another study in Ethiopia, 24 (15.4%) for eggshells and 13 (8.3%) for yolks were found positive for Salmonellosis (30). Two (1.3%) of the 150 carcasses were found contaminated with Salmonella species in Ethiopia (31). From the 300 meat samples examined, 44 (14.7%) were positive for Salmonella including 14.4% (23/160) minced beef, 14.1% (12/85) mutton and 16.4% (9/55) pork samples (32). Salmonellae were isolated from 45 of the 270 samples (16.67%) carried out in Ethiopia (33).

Serotypes and Antimicrobial Resistance of animal Salmonellosis

The most common serotypes identified in Vietnam were S. Agona, S. Emek, and S. London. The identification rates of S. Enteritidis and S. Typhimurium were few (15). The predominant serotypes revealed in a study carried out in South Korea were Salmonella enterica Panama (beef), and Salmonella London and Salmonella Montevideo (chicken meat and pork). All of the isolates of Salmonella species were showed resistance to erythromycin whereas 22.2% for streptomycin and 16.7% for tetracycline and chloramphenicol (24). Five Serotypes of Salmonella including S. Thompson, S. Typhimurium, S. Newport, and S. Hadar were isolated from the chicken meat in Iran. High antimicrobial resistance rates were observed to nalidixic acid (92.8%), tetracycline (81%), streptomycin (56.7%), and kanamycin (36.9%) (16). Eight Salmonella serovars were identified in Louisiana with the predominant serovars of Kentucky, Hadar, and Enteritidis (23) whereas S. Typhimurium was the predominant serovars in Turkey (24).

S. Typhimurium, S. Rubislaw, S. Kiel and S. Derby were the serovars identified in Egypt and were found resistance to ampicillin (57.1%), streptomycin (71.4%), tetracycline (100%), ciprofloxacin (28.6%), chloramphenicol (85.7%) and gentamycin (71.4%) (26).

Different serovars were identified from different areas of Ethiopia. S. Typhimurium, S. Heidelberg, S. reading, S. give, and S. Poona were reported from central Ethiopia (29), S. Muenchen, S. Korovi and S. 1, 4, 5, 12, i :- from Hawassa (30) whereas S.

Infantis, S. Braenderup, S. Anatum, and S. Bovismorbificans, S. Vejle, S. Dublin, S. Saintpaul, S. I: 8:20:- and S. I: 47:z4:z23 from Addis Ababa (32). All of the 45 isolates of Salmonella described in Southern Ethiopia (100%) were resistant to kanamycin and sulfamethoxazole-trimethoprim. Almost all (97.8%) isolates had resistance to ampicillin, nalidixic acid, streptomycin, and tetracycline. Resistance to chloramphenicol and ciprofloxacin was 91.1% and 31.1%, respectively (33).

Results

Eligible and exclusion studies

A total of 222 published articles were searched. Of these, 205 articles were excluded after reviewing their abstracts. The remaining 17 articles have assessed their full text and 3 were excluded due to failure to include antimicrobial susceptibility testing (31–33).

Eleven articles were included in the study. Six of them were eligible to estimate the prevalence of animal salmonellosis and their antimicrobial resistance whereas the remaining five were eligible for serotype and antimicrobial resistance analysis. The selection of eligible studies were based on PRISMA 2009 (35) as illustrated in Fig. 1.

Characteristics of the eligible studies of animal salmonellosis

The characteristics of the eligible studies presented in Table 1. The studies were conducted between 2004 and 2018. Except for two (one from Bahir Dar and one from Wolaita Sodo) studies, all of the eligible studies were carried out in Addis Ababa and Oromia. Seven of the eleven eligible studies were cattle and the majority of the samples collected were fecal materials, caecal content and mesenteric lymph nodes. All of the eligible studies used international organization for standardization (ISO) during isolation, identification, and characterization of salmonella species. Ten of the eligible studies had used buffered peptone water for sample collection as enrichment and all of them were used xylose lysine deoxycholate (XLD) agar for the isolation of Salmonella. Parallel to XLD, brilliant green (BGA) agar in five studies and brilliant green phenol red lactose sucrose (BPLS) agar in three studies were used for the isolation of Salmonella.

Table 1
Characteristics of the eligible studies of animal salmonellosis in Ethiopia.

Author	Location	Study period	Animal	Sample sources	Isolation Method	Samples number	Isolates	Number of drugs	Drug test
(36)	Addis Ababa	2004–2005	Pig	Cc, MLN, L, T, Ma	ISO	501	94	24	Mic
(37)	Addis Ababa	2004–2005	Pig	Cc, MLN	ISO	833	173	24	Mic
(38)	Debre Zeit	2005–2006	Cattle	H, R, Cc, MLN, C	ISO	500	66	24	Mic
(39)	Bahir Dar	2006–2007	Cattle	LT MLN, IC, C	ISO	744	28	8	Dzi
(40)	Addis Ababa	2010	Cow	F, Mil	ISO	390	21	11	Dzi
(41)	Addis Ababa	2013	Cattle	F	ISO	1203	30	18	Dzi
(42)	Wolaita Sodo	2015–2016	Cattle	Ab, Th	ISO	896	56	12	Dzi
(43)	Oromia	2015–2016	Cattle	MLN, F	ISO	300	17	10	Dzi
(44)	Addis Ababa	2013–2014	Poultry	F	ISO	549	26	18	Dzi
(45)	Jimma	2016	Cattle	Cc, F	ISO	390	42	10	Dzi
(46)	Jimma	2018	Egg	ESS	ISO	415	11	12	Dzi
						6721	564		
Cc caecal content, MLN Mesenteric lymph node, L Liver, T tongue, Ma muscle, S spleen, D diaphragm, AM abdominal muscle, F fecal, H hide, R rumen, C carcass, LT Liver tissue, IC intestinal content, Mil Milk, Mt Meat, Ab abdominal, Th thorax, Ch.clo Chicken cloacal, ESS egg surface swab, ISO = International Organizations for Standards, mic = Minimum inhibition concentrations, dzi = Diameter of zone of inhibition									

A total of 6721 samples were collected from pig, cattle, poultry, and eggs and 564(8.4%) *Salmonella* species were identified. Of the eleven eligible studies, the positivity range of *Salmonella* was from 30 (2.5%) in cattle 173 (20.8%) in Pigs from Addis Ababa. The highest prevalence of *Salmonella* was observed in pigs 173 (20.8%) in Addis Ababa followed by pigs 94(18.8%) in Addis Ababa and cattle 66 (13.2%) in Debrezeit. Eight (72.7%) of the eleven studies used the disc diffusion method to test the effect of antimicrobials on the isolated *Salmonella* and measured the diameter of the zone of inhibition (Dzi), Table 1.

Distribution of *Salmonella* Serotypes among animals in Ethiopia

Six studies were eligible for *Salmonella* serotype analysis and 29 serotypes were summarized. Except for one study from Bahir Dar, all of the eligible studies were carried out in Addis Ababa and Debrezeit, Ethiopia. *S. Hadar* was the predominant (74/354, 20.9%) serotype reveal followed by *S. Saintpaul* (55/354, 15.5%), *S. Anatum* (49/354, 13.8%), *S. Eastbourne* (41/354, 11.6%), and *S. Typhimurium* (31/354, 8.8%), respectively, Table 2.

Table 2
Distribution of Salmonella Serotypes among animals in Ethiopia, 2004–2014

Identified Serotype	References, n (%)						Total (%)	Infected animals
	(36)	(37)	(38)	(39)	(41)	(44)		
S. Hadar	38	36	-	-	-	-	74 (20.9)	Pig, pig
S. Saintpaul		29	-	-	6	20	55 (15.5)	Pig, cattle, poultry
S. Anatum	8	2	39	-	-	-	49 (13.8)	Pig, Pig, cattle
S. Eastbourne	1	32	8	-	-	-	41 (11.6)	Pig, Pig, cattle
S. Typhimurium		14	1	6	7	3	31 (8.8)	Pig, pig, cattle, cattle, cattle, poultry
S. Kentucky	15	3	-	-	5	2	25 (7.1)	Pig, cattle, poultry
S. Newport	1	4	13	6	-	-	24 (6.8)	Pig, cattle, cattle
S. Enteritidis	5	4	-	-	-	-	9 (2.5)	Pig
S. Infantis		2	-	5	-	-	7 (2)	Pig, cattle
S. Virchow		-	-	-	5	-	5 (1.4)	Cattle
S. Haifa		-	-	3	-	1	4 (1.1)	Cattle
S. Havana	3	1	-	-	-	-	4 (1.1)	Pig
S. Dublin		-	-	-	3	-	3 (0.8)	Cattle
S. Amager		2	-	-	-	-	2 (0.56)	Pig
S. Kottbus		2	-	-	-	-	2(0.56)	Pig
S. Il 40:b:-		-	2	-	-	-	2(0.56)	Cattle
S. Muenchen		2	-	-	-	-	2(0.56)	Pig
S. Heidelberg		-	-	2	-	-	2(0.56)	Cattle
S. Mishmarhaemek		-	-	2	-	-	2(0.56)	Cattle
S. Uganda	1	-	1	-	-	-	2(0.56)	Cattle
S. Braenderup		1	-	-	-	-	1 (0.28)	Pig
S. Meleagridis		1	-	-	-	-	1 (0.28)	Pig
S. Tarshyne		1	-	-	-	-	1 (0.28)	Pig
S. Bredeney		-	1	-	-	-	1 (0.28)	Cattle

Identified Serotype	References, n (%)						Total (%)	Infected animals
	(36)	(37)	(38)	(39)	(41)	(44)		
S. Urbana		-	1	-	-	-	1 (0.28)	Cattle
S. Aberdeen		-	-	-	1	-	1 (0.28)	Cattle
S. I:6,7,14:-: I,w		-	-	-	1	-	1 (0.28)	Cattle
S. LivingstoneVar.14+		-	-	-	1	-	1 (0.28)	Cattle
S. Mikawasima		-	-	-	1	-	1 (0.28)	Cattle
Total (29 serotypes)	72 (20.3)	136 (38.4)	66(18.6)	24 (6.8)	30 (8.5)	26 (7.3)	354 (100)	

Prevalence and Antimicrobial Resistance of Animal Salmonellosis in Ethiopia

In two of the eligible studies, all of the isolates showed 100% resistance to ampicillin (40, 43) and about 7% (n = 4) and 35% (n = 6) of isolates in two studies revealed resistance to ciprofloxacin (42, 43). Of the five eligible studies analyzed, resistance for ceftriaxone was recorded in two studies (42, 46). A total of 2391 samples were reviewed from the five eligible studies and 147 (6.1%) *Salmonella* species were summarized, Table 3

Table 3
Prevalence and Antimicrobial Resistance of Animal Salmonellosis in Ethiopia

References	Number of Samples	Positive Isolates	Antimicrobial resistance (%)							
			AMP	GEN	CIP	C	S	T	F	CRO
(40)	390	21 (5.4)	21 (100)	4 (19)	0 (0)	2 (9.5)	16 (76.2)	7 (33.3)	13 (61.9)	Nt
(42)	896	56 (6.3)	26 (46.4)	7 (12.5)	4 (7.1)	29 (51.8)	37 (66.1)	47 (83.9)	41 (73.2)	13 (23.2)
(43)	300	17 (5.7)	17 (100)	5 (29.4)	6 (35.3)	0 (0)	7 (41.1)	Nt	5 (29.4)	0(0)
(45)	390	42 (10.8)	13 (31)	3 (7.1)	0(0)	3 (7.1)	10 (23.8)	10 (23.8)	Nt	0(0)
(46)	415	11 (2.7)	10 (90.9)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	7 (63.6)
Total	2391	147 (6.1)	87(59.2)	19 (12.9)	10(6.8)	34 (23.1)	70(47.6)	64(43.5)	59(40.1)	20 (13.6)
AST Antimicrobial test, AMP ampicillin, GEN gentamicin, CIP ciprofloxacin, C chloramphenicol, S streptomycin, T tetracycline F nitrofurantoin, CRO ceftriaxone, Nt Not tested.										

Of the total 147(6.1%) *Salmonella* species summarized, 89 (60.5%), 70 (47.6%) and 64(43.5%) isolates were found resistant for ampicillin, streptomycin, and tetracycline, respectively. The antibiotics that showed less resistance were ciprofloxacin 10 (6.8%), gentamicin 21 (12.9%) and ceftriaxone 20 (13.6%), respectively, Fig. 2.

Salmonella Serotype and their antimicrobial resistance in animals

Six studies were included to assess the antimicrobial resistance of serotypes of animal salmonellosis. In each of the eligible studies, top isolates of 12 serotypes comprising 204 isolates were selected to check their resistance status. Accordingly, of the 47 serovars of *S. Hadar*, 97.9% were resistant to streptomycin and tetracycline (37). Two (22.2%) of the nine tested *S. Typhimurium* showed resistance to ampicillin, ciprofloxacin, chloramphenicol, streptomycin, and tetracycline (37) and similarly, one of the six (16.7%) tested *S. Typhimurium* was found resistant to chloramphenicol, streptomycin, and tetracycline (39). In another study, three *S. Typhimurium* was tested and all of them were resistant to streptomycin and one (33.3%) to tetracycline (41) although no resistance was observed for the seven, tested *S. Typhimurium* in a study carried out by Eguale (44).

All of the isolates ($n = 5$) of *S. Kentucky* showed resistance for ampicillin and ciprofloxacin but 80% ($n = 4$) for streptomycin and tetracycline (37). Similarly, five isolates of *S. Kentucky* in a study carried out by Eguale (41) and two isolates of *S. Kentucky* in another study by Eguale (44) were tested and all of them were resistance for ampicillin, gentamycin, ciprofloxacin, streptomycin and tetracycline, Table 4.

Table 4
Salmonella Serotype and antimicrobial resistance in animals in Ethiopia

Author	S. Serotypes tested	Antimicrobial Resistance (%)						
		AMP	GEN	CIP	C	S	T	F
(36)	S. Hadar (n = 38)	-	-	-	-	37 (97.4)	38 (100)	37 (97.4)
	S. Kentucky (n = 15)	-	1(6.7)	15 (100)	-	12 (80)	14 (93.3)	-
	S. Enteritidis (n = 5)	-	-	5 (100)	-	-	-	5(100)
(37)	S. Hadar (n = 47)	0(0)	0(0)	0(0)	0(0)	46 (97.9)	46 (97.9)	44 (93.6)
	S. Typhimurium (n = 9)	2 (22.2)	0(0)	2 (22.2)	2 (22.2)	2 (22.2)	2 (22.2)	0(0)
	S. Kentucky (n = 5)	5 (100)	2 (40)	5 (100)	0(0)	4 (80)	4 (80)	0(0)
(38)	S. Anatum (n = 39)	0(0)	0(0)	0(0)	0(0)	1(2.6)	2 (5.1)	0(0)
	S. Newport (n = 13)	0(0)	0(0)	0(0)	0(0)	3 (23)	10 (77)	0(0)
	S. Eastbourne (n = 8)	0(0)	0(0)	0(0)	0(0)	0(0)	1 (12.5)	0(0)
(39)	S. Typhimurium (n = 6)	0(0)	0(0)	0(0)	1(16.7)	1(16.7)	1(16.7)	0(0)
	S. Newport (n = 6)	0(0)	0(0)	0(0)	0(0)	4 (66.7)	0(0)	0(0)
	S. Infantis (n = 5)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	S. Haifa (n = 3)	2 (66.7)	0(0)	0(0)	0(0)	3 (100)	2 (66.7)	0(0)
(41)	S. Dublin (n = 3)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	S. Kentucky (n = 5)	5 (100)	5 (100)	5 (100)	0(0)	5 (100)	5 (100)	0(0)
	S. Saintpaul (= 6)	0(0)	0(0)	0(0)	0(0)	1(16.7)	0(0)	0(0)
	S. Typhimurium (n = 7)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	S. Virchow (n = 5)	3 (60)	1(20)	0(0)	0(0)	2 (40)	1(20)	0(0)
(44)	S. Saintpaul (= 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
	S. Haifa (n = 1)	0(0)	0(0)	0(0)	0(0)	1 (100)	1 (100)	1 (100)
AMP Ampicillin, GEN Gentamycin, CIP Ciprofloxacin, C Chloramphenicol, S Streptomycin, T Tetracycline, F Nitrofurantoin								

Discussion

Salmonellosis is one of the public health problems of humans and animals in both developed and developing countries (34). Animals are the main reservoirs of human Salmonellosis (12, 13) though vegetable foods contaminated by animal products and human excreta have been implicated as the automobile of human salmonellosis (14). Consumption of animal food from infected animals or from the contamination of carcasses (10) such as cattle, swine, and sheep (11) are the main sources of non-Typhoidal Salmonella and the leading cause of zoonotic foodborne diseases.

In this review, 6721 samples (cattle, pig, poultry, and eggs) were collected from 11 eligible studies to assess the prevalence of animal Salmonellosis in Ethiopia. A total of 564 Salmonella species were identified and 8.4% was found to be a pooled

prevalence of salmonella species in animals in Ethiopia.

This pooled prevalence (8.4%) was in line with studies carried out in Ethiopia (40, 42, 43, and 45). Hence, there were studies in the same country which showed lower (29, 31, 39, 41, 44 and 46) and higher (30, 31, 33, 36–38) prevalence with a range of 1.3% (29) to 23.7% (28). This was also in line with studies carried out in Nigeria (28), Burkinafaso (47) and Italy (48) but lower than studies from Vietnam (15), China, (21), Louisiana (23), Kenya (49), South Africa (50) and Uganda (51).

A total number of 354 serotypes were summarized from six studies and named into 29 serotypes of salmonella. Cumulatively, the following serotypes were ordered from the highest to the lowest starting from S. Hadar 74 (20.9%), S. Saintpaul 55(15.5%), S. Anatum 49 (13.8%), S. Eastbourne 41 (11.6%), S. Typhimurium 31 (8.8%), S. Kentucky 25 (7.1%), S. Newport 24 (6.8%) and S. Enteritidis 9 (2.5%). However; each of the serotypes had their own predomination in the different studies such as S. Hadar in two studies (36, 37), S. Anatum in one study (38), S. Typhimurium from dairy cattle (44), slaughtered sheep and goat (27), and in humans (52) in Addis Ababa, Ethiopia. Likewise, S. Typhimurium was reported as a predominant from chicken meat in Egypt (53) and retail meat in Turkey (24), poultry and poultry products in India (54), vegetables in Mexico (55), and China (56).

S. Typhimurium and S. Enteritidis are stated as the common NTS serotypes in Sub Saharan Africa that are associated with invasive infection in humans (57–59). The presence of such salmonella prevalence in cattle, poultry, pigs and other animal sources possibly considered as a potential sources of contamination in humans and may the main risk factors for the Salmonella outbreaks in humans (60, 61).

In spite of the fact that ceftriaxone (cephalosporin) and ciprofloxacin (quinolones) has not been used for the treatment of animal salmonellosis in Ethiopia. However; ceftriaxone resistance species of salmonella has reported in two studies in Ethiopia (42, 46) although the serotype level ceftriaxone resistance report was not found. Similarly, ciprofloxacin resistance of Salmonella was reported in species (42, 43) and serotype level in Ethiopia (36, 37, 41, and 44). All of the isolates of S. Kentucky in four studies in Ethiopia showed resistance to ciprofloxacin (36, 37, 41, and 44) though S. Kentucky was not demonstrated in other studies in Ethiopia (29, 38, 39, 62, and 63).

Twelve serotypes having 204 isolates were found eligible to assess the antimicrobial resistance. Six serotypes showed multidrug resistance comprising 120 isolates. The predominant serotype that showed MDR (to three antibiotics) was S. Hadar 81 (67.5%) (36, 37) followed by S. Kentucky 22(18.3%) (36, 37, 41, 44), Table 5.

Table 5
Multidrug-resistant (MDR) Serotypes of Salmonella isolates of animal sources

Serotypes	Infected host	Resistant isolates	MDR pattern	Author
S. Typhimurium	Pig	2	Amp, Cip, C, S, T	(37)
	Cattle	1	C,S,T	(38)
	Poultry	1	S, T, F	(44)
S. Kentucky	Pig	2	Amp, Gen, C, S, T	(37)
	Pig	2	Amp, Cip, S, T	(37)
	Cattle	5	Amp, Gen, Cip, S, T	(41)
	Poultry	1	Amp, Gen, Cip, C, S, T	(44)
	Poultry	1	Amp, Gen, Cip, S, T	(44)
	Pig	1	Gen, Cip, S, T	(36)
	Pig	10	Cip, S, T	(36)
S. Saintpaul	Poultry	4	Amp, C, S, T, F	(44)
	poultry	1	Amp, C, S, F	(44)
	poultry	4	Amp, C, S	(44)
S. Haifa	cattle	2	Amp, T, F	(39)
	Poultry	1	S, T, F	(44)
S. Hadar	Pig	37	S, T, F	(36)
	Pig	44	S, T, F	(37)
S. Virchow	cattle	1	Amp, Gen, S, T	(41)
AMP Ampicillin, GEN Gentamycin, CIP Ciprofloxacin, C Chloramphenicol, S Streptomycin, T Tetracycline, F Nitrofurantoin				

Conclusions

Eleven studies were found eligible to carry out a systematic review in animal salmonellosis in Ethiopia. Five of them were eligible to analyze the prevalence of Salmonella species and their antimicrobial resistance whereas the other six were eligible to assess the prevalence of Salmonella in serotype level. We selected eight commonly tested antimicrobials in species level (ampicillin, gentamycin, ciprofloxacin, chloramphenicol, streptomycin, tetracycline, nitrofurantoin, and ceftriaxone) whereas seven in serotype level (ampicillin, gentamycin, ciprofloxacin, chloramphenicol, streptomycin, tetracycline, and nitrofurantoin).

From the 11 studies, 6721 samples were collected and the sources of samples were pigs, cattle, poultry, and eggs. The overall number of positive isolates of Salmonella revealed from the 11 eligible studies were 564(8.4%).

Twenty-nine Salmonella serotypes were extracted from the six eligible studies which comprised a total number of 354 serotypes. Of the total 354, the contribution of each of the twenty-one serotypes had less than 2% whereas the other eight serotypes have a range from 74 (20) in S. Hadar to 9 (2.5%) in S. Enteritidis. Salmonella enterica serovars Newport and Salmonella enterica serovars Typhimurium have multiple host ranges (Table 2).

Of the total 147(6.1%) *Salmonella* species summarized from the five eligible studies, 89 (60.5%), 70 (47.6%) and 64(43.5%) isolates were found resistant for ampicillin, streptomycin, and tetracycline, respectively. Less resistant were observed in ciprofloxacin 10 (6.8%), gentamicin 21 (12.9%) and ceftriaxone 20 (13.6%) (Fig. 2).

Twelve serotypes having 204 isolates were found eligible to assess the antimicrobial resistance. Six serotypes showed multidrug resistance comprising 120 isolates. The predominant serotype that showed MDR (to three antibiotics) was *S. Hadar* 81 (67.5%) followed by *S. Kentucky* 22(18.3%).

Methods

Eligibility Criteria

The eligibility criteria of this study included publication in English, cross-sectional study, samples of food animal origin, microbial isolation, identification, and antimicrobial sensitivity test methods, and the number of tested isolates and antimicrobial susceptibility testing.

Literature search strategies

Articles related to animals, human salmonellosis were searched in Google Scholar and PubMed. The terms used to search the articles were prevalence, epidemiology, incidence, *Salmonella*, distribution, antimicrobial resistance, animals, humans, and food. The search covered published articles up to December 30, 2019.

Data extraction

Author, location, study period, animal name, sample sources, isolation method, number of animals, number of Samples, Positive (%)/sample, number of drugs, drug test. Serotypes were also extracted from some of the studies. The prevalence of non-typhoidal *Salmonella* was calculated by using the numbers of isolates as a nominator and the total samples as the denominator.

Abbreviations

ISO International Organizations for Standardization, PRISMA Preferred Reporting Items for Systematic Review and Meta-Analysis, MDR Multidrug-resistant, XLD Xylose lysine Deoxycholate, BGA Brilliant Green Agar

Declarations

Ethics approval and consent to participate: Not applicable

Consent for publication: Not applicable

Availability of data and material: All the data used to write this manuscript are available on hand and I can share up on call.

Competing interests: The author declare that I have no competing interests.

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Authors' contributions

AGK was involved in data collection, analysis, drafting the review manuscript and critically reviewing the manuscript.

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Figures

Figure 1

A flow diagram of the selection of the eligible studies

Figure 2

Pooled drug-resistant profile of animal salmonellosis