Prevalence and antimicrobial resistance patterns of *Salmonella* isolates in human stools and animal origin foods in Ethiopia: A systematic review and meta-analysis

Degu Abate¹, Nega Assefa²

¹Department of Medical Laboratory Sciences, College of Health and Medical Sciences, Haramaya University, P.O. Box, 235, Harar, Ethiopia, ²School of Nursing and Midwifery, College of Health and Medical Sciences, Haramaya University, P.O. Box, 235, Harar, Ethiopia

**ABSTRACT**

**Objective:** Foodborne diseases caused by non-typhoid *Salmonella* and the emergence of antimicrobial resistance remain as a public health challenge, especially in developing countries. The current study aimed to estimate the pooled prevalence and the antimicrobial resistance patterns of non-typhoid *Salmonella* in Ethiopia.

**Methods:** Literature search was conducted from major electronic databases and indexing services. Both published and unpublished studies addressing the prevalence and antimicrobial resistance profiles of *Salmonella* in Ethiopia from 2010 to 2020 and those studies reported sample size and the numbers of isolates/number of positive samples were included in the study. Data were extracted using format prepared in Microsoft Excel. The identified data were exported to EndNote to remove duplicated studies, then after the remained articles were screened using title, abstract, and full text to identify studies that meet the inclusion criteria and finally appraised for methodological validity using JBI guideline. The pooled prevalence of *Salmonella* and its drug resistance pattern was computed by a random-effects model. I² test statistic was used to test heterogeneity across studies. The presence of publication bias was evaluated using the Begg’s and Egger’s tests.

**Results:** A total of 49 eligible articles, 33 of them on human stools, 15 of them on animal origin foods, and one both on human stools and animal origin foods, were included in the study. The pooled prevalence of *Salmonella* among human stools and animal origin foods in Ethiopia was 4.8% (95% CI: 3.9, 5.9) and 7.7% (95% CI: 5.6, 10.4), respectively. The subgroup analysis detected high pooled prevalence, 7.6% (95% CI: 5.3, 10.7) among outpatients and low, 3.7% (95% CI: 2.6, 5.1) in food handlers. The pooled resistant level of *Salmonella* was 80.6% (95% CI 72.6, 86.7) for ampicillin and 63.5% (95% CI 53.7, 72.4) for tetracycline. Low pooled resistance pattern was reported in ciprofloxacin, 8.7% (95% CI 5.6, 13.3) and ceftriaxone 12.2% (95% CI 7.9, 18.3). There was some sort of publication bias.

**Conclusion:** High pooled prevalence of *Salmonella* among human stools and animal origin foods which were 4.8% and 7.7% respectively, and high *Salmonella* resistance, >72% to ampicillin and tetracycline were detected in Ethiopia. Antimicrobial stewardship efforts and infection control strategies are required to mitigate this major public health concern.

**Keywords:** Animal origin food, antimicrobial resistance, Ethiopia, human stool, *Salmonella*

**Background**

Nontyphoidal *Salmonella* are a leading cause of foodborne illness responsible for more than 93 million cases of gastroenteritis and about 155,000 deaths each year.¹¹ Foodborne diseases caused by non-typhoid *Salmonella* still remains as a public health challenge. All countries around the globe are suffering from foodborne disease outbreaks. However, the relative contributions of animal products to human salmonellosis differ across countries. For instance, beef is reported to be the vector of 7% of the 1.7 million cases of foodborne disease in England and Wales² and out of more than one million people sickened by *Salmonella* each year in the United States, poultry was the pathogenic vehicle for 20%
The problem is more serious in developing
countries, where more than one billion cases of gastroenteritis
are reported and five million individuals die annually.[14]

Nontyphoidal Salmonella enters the food chain at any point
in livestock feed and in food processing. Apart from sporadic
infections, outbreaks associated with the consumption of
contaminated animal products have been recorded in several
countries. Poultry and other food animals are considered the
common reservoirs of Salmonella where undercooked food
products mainly consumption of contaminated food of animal
origin such as poultry products, beef, and pork as well as
contact with infected animals are the major sources of human
infection with nontyphoidal Salmonella.[5,6]

The emergences of antimicrobial-resistant Salmonella spp.
are other global challenges, especially in developing countries
where there is an increased misuse of antimicrobial agents
in humans as well as in animals and is associated with a variety
of biological, pharmacological, and societal variables with the
worst combinations in developing countries.[17] Antimicrobial-
resistant Salmonella is one of the global problems in present-
day clinical practices, and recently, a strain on the verge of
pan-resistance was reported.[18] The prevalence of multidrug
resistance (MDR) Salmonella has increased and outbreaks
due to MDR strains were reported in sub-Saharan Africa.[9,10]
Infections with MDR pathogens are associated with excess
morbidity and mortality, probably because of the co-selection
of traits of drug resistance and virulence.[11]

In developing countries including Ethiopia, where a high frequency
of resistant Salmonella spp. against different antimicrobial agents
have been reported,[12] the therapeutic management of the disease
is difficult because isolation of Salmonella spp. in most laboratories
remains a challenge due to inadequate laboratory facilities required
for the accurate detection of bacteria and to perform antimicrobial
susceptibility testing.[17] Hence, drug sensitivity tests are not
routinely carried out and treatment alternatives are not available
in most health care facilities.[13,14]

Moreover, surveillance and monitoring systems are not in
place and the pharmacoepidemiology of the bacteria among
the different population and their food is not well described
despite the importance of the disease caused by the bacteria.
However, pooling previous prevalence and antimicrobials
susceptibility patterns among human stools and animal origin
foods could provide insight about the overall pooled prevalence
of the isolates and the proportions of drug-resistant isolates
reported by different cross-sectional studies. Therefore, the
main aim of this study was to estimate the pooled prevalence
and antimicrobial susceptibility of Salmonella in human stool
and animal origin food specimens using systematic review
and meta-analysis. The findings of this systematic review and
meta-analysis are expected to provide evidence for policy
formulation, prevention, and control of Salmonellosis and
Antimicrobial resistance in human and animals.

Methods

Study protocol

The Preferred Reporting Items for Systematic Reviews and
Meta-analysis (PRISMA) reporting items were followed for
reporting of identification of records, screening of titles and
abstracts as well as evaluation of eligibility of full texts for final
inclusion to ensure inclusion of relevant information/studies
into this systematic review and meta-analysis.[15] PRISMA
checklist was also strictly followed while conducting this
systematic review and meta-analysis. The protocol of this
systematic review and meta-analysis has been submitted for
registration in the Prospero database. Two authors (DA and
Na) independently screened the titles and abstracts of studies
with predefined inclusion criteria. Two authors (DA and NA)
also independently collected full-texts of studies and evaluated
the eligibility of them for final inclusion.

Inclusion criteria

All Prospective cross-sectional studies aimed to assess
prevalence and antimicrobial susceptibility patterns of
Salmonella by collecting human stools from food handlers
working in towns and universities student cafeteria or
restaurants, patients including under-five children that sought
medical service for reasons of gastroenteritis/diarrhea, and
foods of animal origin (restricted to raw egg, milk, and meat
produced for human consumption) samples in Ethiopia that
were conducted/published from 2010 to 2020 were included
in the study. Studies reported both sample size of the study
and the numbers of isolates/number of positive samples, and
published in English language, the articles reported detection
by culture and confirmed by biochemical test of Salmonella,
determine antimicrobial resistance patterns for ceftriaxone
(CRO, 30 μg), chloramphenicol (C, 30 μg), ciprofloxacin
(CIP, 5 μg), gentamicin (GM, 10 μg), ampicillin (AMP, 10 μg),
and tetracycline (T, 30 μg) using disk diffusion method and
defined antimicrobial resistance range according to according
to the Clinical Laboratory Standards Institute were included
in the study.[16]

Exclusion criteria

Studies that were conducted on target population with a
pre-existing medical condition such as HIV, diabetic, and
other chronic conditions, used microscopic, molecular,
and serological methods to detect and isolate Salmonella,
not reported the numerator (i.e., number positive) and
denominator (i.e., number tested) information by sample
type (human stool and food of animal origin), and all
review articles and original articles conducted outside of
Ethiopia were excluded from the study. And also, articles
with irretrievable full texts, records with unrelated outcome
measures, and articles with missing or insufficient outcomes,
and also studies which did not adhere to standard operating
procedures were excluded from the study.
Search strategy and identification of studies

The search strategy used aimed to find both published and unpublished articles. The data were collected by searching articles published in English from electronic databases and indexing services such as PubMed/Medline, Google Scholar, Embase, Direct Science, World cat, and University repositories which were used as the main source of data. The reference list of identified articles was also searched for additional studies. Subject headings relevant to each database were used, like MeSH term for PubMed/Medline. In addition, Google and hand searching were employed to retrieve grey literature. Salmonella* and Ethiopia were the main MeSH terms in electronic searches. The additional search terms used in this review were “Foodborne pathogen,” “diarrhea/diarrhea,” “antimicrobial resistance,” “antibiotic resistance,” “humans,” “animals,” “and a specific region name” that appeared in the title, abstract, or keywords. The Boolean logical connectors (AND and OR) and truncation were applied for appropriate search and identification of records for the research question. Articles published from 2010 to 2020 were included in the study. The last search was conducted on March 24, 2020.

Study selection

Articles identified from various electronic databases, indexing services, and directories were exported to EndNote reference software version 8,[17] which was used to remove duplicated studies. After duplicates were removed using EndNote, some duplicates were addressed manually due to variation in reference styles across sources. The titles and abstracts were screened to identify studies that potentially meet the inclusion criteria. Full-text articles were reviewed to determine if each article met predetermined inclusion and exclusion criteria. Studies that are deemed to meet inclusion by title/abstract screening undergone full-text appraisal for methodological validity using standardized critical appraisal instruments from the Joanna Briggs Institute (JBI) Instrument.[18] Full texts of articles that were selected to be included were extracted systematically using the Excel sheet.

Data extraction

From each included article, data such as author, year of study/publication, location/region, mean age with standard deviation, sample size, isolation/identification methods, number of Salmonella isolated or detected, and number of antimicrobial-resistant isolates against the selected antimicrobial agents, number of MDR isolates, study design, sampling technique, and sample types were extracted using standardized data abstraction format prepared in Microsoft Excel. During data extraction conditions and time of transport to laboratory, amount of sample tested, media used, and temperature and gas conditions of incubation were considered.

Quality assessment

The articles were assessed prior to inclusion to maintain methodological validity using the JBI critical appraisal checklist for studies reporting prevalence data by two authors. The assessment tool consisted of nine questions about the quality of the study for which articles receive values representing the extent to which they met criteria using Yes, No, Unclear, and Not applicable reply to each nine questions. This critical appraisal was conducted to assess the internal (systematic error) and external (generalizability) validity of studies and to reduce the risk of biases. The mean score of two authors was taken for final decision and studies with a score yes, greater than or equal to five were included in the study.[19]

Outcome measurements

The primary outcome measure is the prevalence of Salmonella among human stools and animal origin foods in Ethiopia, which was calculated by dividing the numbers of Salmonella isolates by the total number of examined samples (study participants). The secondary outcome is antimicrobial resistance patterns of Salmonella isolated from human stools and animal origin foods in Ethiopia which was also calculated by dividing the numbers of resistant Salmonella isolates against the selected antimicrobial agents (CRO, 30 μg, C, 30 μg, CIP, 5 μg, GM, 10 μg, AMP, 10 μg, and T, 30 μg) by the total number of isolated Salmonella. This systematic review and meta-analysis are aimed to assess the pooled estimates of prevalence and antimicrobial resistance profile of Salmonella among human stools and animal origin of foods in Ethiopia. Subgroup analysis was also conducted among different study participants and types of food of animal origin.

Data processing and analysis

After extraction of relevant data from studies that were included into the study using format prepared in Microsoft Excel, data were entered into comprehensive meta-analysis software version 3 to analyze pooled estimate of outcome measures and subgroup analyses. Subgroup analysis of the primary outcome (prevalence of Salmonella) was done based on study participants/type of food, locations/directions of the country, and year of studies categories. The methodological validity of individual studies included in this study was assessed using the JBI critical appraisal checklist to assess the validity of studies and to reduce the risk of biases, considering variation in true effect sizes across study population, locations/directions of country, and year of studies, random-effects model was used for the analysis at 95% confidence level. The significance of heterogeneity of the studies was assessed using I^2 statistics. P < 0.05 was used to define a significant degree of heterogeneity within studies. Publication bias was assessed using comprehensive meta-analysis software and presented using with funnel plots of the standard error of Logit event rate along with testing its asymmetry using Beggs’s and Egger’s test (Begg and Mazumdar, 1994, Sterne and Egger, 2001).

Results

Search results

A total of 339 potentially relevant studies published from 2010 to 2020 were identified by online searching electronic database...
such as PubMed/MEDLINE, Google Scholar, Embase, Science Direct, and Worldcat. From where 162 duplicated articles were removed with the help of EndNote and manual tracing. The remaining 177 articles after removing duplicates were screened using their titles, by which 75 articles were excluded from the study. The 102 articles selected by title screening were further screened using their abstracts. By abstract screening, 32 articles were removed. The remaining 70 articles were evaluated by reviewing full text against eligibility criteria and PRISMA statement.\textsuperscript{[15]} From these, 21 articles were excluded due to the outcome of interest missed/different, sample size was not mentioned, used Salmonella isolates from stoke/storage, different/absence of study design, and Poor-quality assessment results.

Finally, a total of 49 articles those fulfilled the eligibility criteria and quality assessment were included for systematic review and meta-analysis [Figure 1]. The included articles were divided into two groups, those articles which gave a report about Salmonella prevalence or antimicrobial resistance patterns among human stool or animal food origin. Some studies reported both prevalence and antimicrobial resistance of Salmonella.

**Study characteristics**

A total of 49 eligible articles, 33 of them on human stools, 15 of them on animal origin foods, and one of them on both human stools and animal origin foods, were included in this systematic review and meta-analysis. All the included articles were cross-sectional study design in study type. The included articles were carried out on stools of humans with different age groups and animal food types included raw meat, egg, and milk.

Among 34 articles that were conducted on human stools, eight articles were done on under-five children with diarrhea,\textsuperscript{[19-26]} 13 articles were on food handlers who were working in different town’s and universities’ student cafeterias and restaurants,\textsuperscript{[14,27-38]} eight articles were done on general outpatients (all age group) with diarrhea,\textsuperscript{[12,39-45]} and five articles were on diarrheic children with age up to 14 years.\textsuperscript{[46-49]} From 34 articles describing prevalence of Salmonella on human stool that were included in this review and meta-analysis, most of them were conducted in southern (13 articles), northern (9 articles), and central (8 articles) Ethiopia. Three and only one articles were conducted in eastern and western Ethiopia, respectively [Table 1].

Out of 16 articles on animal origin foods: 6, 3, and 7 of them were on meat,\textsuperscript{[42,50-54]} egg,\textsuperscript{[55-57]} and milk,\textsuperscript{[58-64]} respectively. From 16

---

**Figure 1:** PRISMA flow chart describing the selection process of articles used for systematic review and meta-analysis
**Table 1:** Characteristics of the studies describing the prevalence of *Salmonella* isolates in Human stools in Ethiopia published/done from 2010 to 2020

| Author, year          | Study area                        | Sampling technique | Target population   | Sample size | Number of isolates (%) |
|-----------------------|-----------------------------------|--------------------|---------------------|-------------|------------------------|
| Getnet *et al.*, 2014 | Addis Ababa University            | S.R                | Food handlers       | 233         | 8 (3.43)               |
| Aklihu *et al.*, 2015 | Addis Ababa University            | S.R                | Food handlers       | 172         | 6 (3.5)                |
| Solomon *et al.*, 2018 | Sodo Town, S.E                    | Not stated          | Food handlers       | 387         | 35 (9.04)              |
| Awol *et al.*, 2019   | Hawasa city                       | S.R                | Food handlers       | 236         | 5 (2.12)               |
| Tosisa *et al.*, 2020 | Ambo Health F.                    | Not stated          | U5 Children         | 239         | 3 (1.3)                |
| Bafa *et al.*, 2019   | Wolkite University                | S.R                | Food handlers       | 170         | 10 (5.9)               |
| Getie *et al.*, 2019  | Gonder town                       | Not stated          | Food handlers       | 257         | 3 (1.2)                |
| Feleke *et al.*, 2018 | Wegera District, Amhara           | Not stated          | U5 Children         | 225         | 2 (0.9)                |
| Mamu and Alemu, 2016  | Arba Minch University             | S.R                | Food handlers       | 345         | 24 (7)                 |
| Garedew            | Gonder University                | Not stated          | Food handlers       | 423         | 13 (3.1)               |
| Gebreyesus *et al.*, 2014 | Mekelle University               | Not stated          | Food handlers       | 307         | 3 (1)                  |
| Yesigat *et al.*, 2020 | Motta town                       | Not stated          | Food handlers       | 243         | 6 (2.5)                |
| Endalu, 2019        | Arba Minch University             | S.R                | Outpatient          | 122         | 7 (5.74)               |
| Bayeh *et al.*, 2010 | Bahir Dar University             | Random              | Food handlers       | 410         | 11 (2.7)               |
| Gebreziabher *et al.*, 2018 | Mekele University             | Not stated          | Children            | 260         | 19 (7.31)              |
| Hayamo *et al.*, 2019 | Alamura HC, S.E                  | Convience           | Children            | 263         | 1 (0.4)                |
| Beyene *et al.*, 40   | TAUHLA.A                         | Convience           | Children            | 825         | 55 (6.7)               |
| Beyene and Tasew     | Jima Specialized University H.    | Convience           | Children            | 400         | 10 (2.5)               |
| Yemane *et al.*, 2014 | Bahar Dar town                   | Purposive           | U5 children         | 422         | 33 (7.82)              |
| Ameyo *et al.*, 2018  | Arba Minch, HC+H                 | Sy.R               | U5 children         | 167         | 21 (12.6)              |
| Getamesay *et al.*, 2014 | Hawasa, Adare H and Millennium HC | Convience           | U5 children         | 158         | 4 (2.53)               |
| Abebe *et al.*, 2018  | Nigist Eleni Mohammed Hospital, Southern, Hosanna | Convience           | U5 children         | 204         | 2 (1)                  |
| Assefa and Girma, 2019 | Robe General and Goba H          | S.R                | U5 children         | 422         | 29 (6.9)               |
| Lamboro *et al.*, 2017 | Jima, USH                        | Not mentioned       | Outpatient          | 176         | 19 (11)                |
| Demissie           | Gonder Town Health F             | Sy.R               | Outpatient          | 372         | 4 (1.1)                |
| Eguale *et al.*, 2015 | A.A HC and TASH                  | Not stated          | Outpatient          | 957         | 59 (6.2)               |
| Teshome *et al.*, 2019 | Adama Public Health F            | Not stated          | Outpatient          | 232         | 20 (8.6)               |
| Tadesse *et al.*, 2019 | Dire Dawa city                  | S.R                | Food vendors        | 218         | 13 (6)                 |
| Marami *et al.*, 2018 | Haramaya University              | Sy.R               | Food handlers       | 422         | 15 (3.6)               |
| Terfassa and Jida, 2018 | Nekente Referral H               | Not stated          | Outpatient          | 422         | 30 (7.1)               |
| Adimasu *et al.*, 2014 | Hiwot Fana Hosp. Harar          | Convience           | Outpatient          | 384         | 56 (14.6)              |
| Getachew *et al.*, 2014 | Butajira Health Center          | Not stated          | Outpatient          | 382         | 40 (10.5)              |
| Mamu and Alemu, 2015 | A.A HC and TASH                  | Convience           | U5 children         | 253         | 10 (4)                 |

A.A: Addis Ababa, HC: Health Center, H: Hospital, TASH: Tikur Anbessa Specialized Hospital, USH: University Specialized F: Facility Hospital, S.R: Simple Random, Sy.R: Systematic Random, U5: Under five age, S.E: South Ethiopia

Articles describing prevalence of *Salmonella* in animal origin foods that were used in this review and meta-analysis, most of them were conducted in central (7/16), northern (4/16), southern (4/16), and only one in eastern Ethiopia. No study on *Salmonella* prevalence in animal origin food was obtained from western Ethiopia [Table 2].

**Quality assessment result**

The quality score of included articles ranges from 56% to 89% as per JBI critical appraisal checklist for studies reporting prevalence data. Two studies were excluded from systematic review and meta-analysis since they scored <56%.

**Primary outcome**

*Prevalence of Salmonella in human*

A total of 34 articles, with 10,968 study participants from where 592 *Salmonella* isolates were isolated, were used in this meta-analysis. The 34 included studies revealed that the pooled prevalence of *Salmonella* among human stools in Ethiopia was
4.8% (95% CI: 3.9, 5.9) [Figure 2]. High heterogeneity was observed across the included studies ($I^2 = 82.47, P < 0.001$). Therefore, a random effect meta-analysis model was computed to estimate the pooled prevalence of Salmonella among Human Stools in Ethiopia.

### Subgroup analysis prevalence of Salmonella among human stools

In this meta-analysis, the subgroup analysis was performed based on study populations, the location/direction of the country where studies were conducted as well as the year of study. Accordingly, the subgroup analysis detected that the highest pooled prevalence was detected among outpatients which were 7.6% (95% CI: 5.3, 10.7), followed by children, 4.7% (95% CI: 2.9, 7.6), under-five children, 3.9% (95% CI: 2.3, 6.6), and food handlers, 3.7% (95% CI: 2.6, 5.1) with $I^2$ values of the Logit event estimates in children, food handlers, outpatients, and under-five children were 77.02%, 75.59%, 85.32%, and 83.25%, respectively ($P = 0.000$). The subgroup analysis based on location indicated that pooled prevalence was 7.0% (95% CI: 2.7, 16.9) in eastern Ethiopia, 5.6% (95% CI: 4.1, 7.8) in southern Ethiopia, 5.2% (95% CI: 3.9, 6.8) in central Ethiopia, and 2.6% (95% CI: 1.5, 4.4) in northern Ethiopia. Pooled estimates for Western Ethiopia were not calculated due to insufficient data (only one article). The $I^2$ values of the Logit event estimates in Central, eastern, northern, and southern Ethiopia were 60.08%, 93.38%, 83.70%, and 80.36%, respectively ($P = 0.000$). With regard to the year of study, the prevalence of Salmonella was 4.3% (95% CI: 2.8, 6.5) and 5.0% (95% CI: 3.9, 6.3) from studies that were published from 2010 to 2015 and 2015 to 2020, respectively [Table 3]. The $I^2$ values of the Logit event estimates in the 2010-2015 and 2015-2020 were 89.74% and 75.96%, respectively ($P = 0.000$).

### Prevalence of Salmonella in animal origin foods

A total of 16 articles with 4426 study participants from where 380 Salmonella isolates were isolated were included in this meta-analysis that was conducted to determine the pooled prevalence of Salmonella in animal origin foods. The analysis of 16 studies showed that the pooled prevalence of Salmonella in animal origin foods in Ethiopia was 7.7% (95% CI: 5.6, 10.4) [Figure 3]. High heterogeneity was observed across the

![Figure 2: Forest plot of the pooled prevalence of Salmonella among Human stools in Ethiopia](image-url)
Table 2: Characteristics of the studies describing the prevalence of Salmonella isolates in Animal Origin Foods in Ethiopia published/done from 2010 to 2020

| Author, year | Study area | Sampling technique | Participants | Sample size | Number of isolates |
|--------------|------------|--------------------|--------------|-------------|-------------------|
| Endalu, 2019[42] | Adama | S.R | Meat | 66 | 4 (6.1) |
| Zelalem, 2017[34] | Dukem | Sy.R | Meat | 118 | 15 (12.7) |
| Tesfaw et al.,[44] | A.A, Dairy product | S.R | dairy product | 384 | 6 (1.6) |
| Mulaw, 2017[23] | Dairy farm of Bahir Dar town | Not stated | Milk | 384 | 36 (9.4) |
| Abebe et al., 2014[30] | Tigray Woreda | S.R | Meat | 384 | 63 (16.4) |
| Tadesse and Dabassa, 2012[63] | Kersa District, Jima | Random | Milk | 100 | 20 (20) |
| Abate et al., 2013[38] | Sebeta | Random | Milk | 100 | 16 (16) |
| Assefa et al., 2011[19] | Kombolcha poultry multiplication and market | S.R | Egg | 400 | 46 (11.5) |
| Tsegaye et al., 2016[57] | Alage, Ziway, Shashamane | Sy.R | Egg | 392 | 52 (13.3) |
| Taddese et al., 2019[60] | Jima town | Not stated | Egg | 415 | 11 (2.7) |
| Ejo et al., 2026[64] | Animal origin food items in Gonder | S.R | Animal-origin food | 384 | 21 (5.5) |
| Mengistu et al., 2017[51] | Dire Dire town and HU Slaughterhouses and retail shops | Not stated | Meat | 290 | 8 (2.8) |
| Addis et al., 2011[19] | A.A dairy farm | Not stated | Milk | 195 | 6 (3.1) |
| Asfaw Ali et al.,[51] | Debret Zeit and Modjo | Sy.R | Meat | 384 | 56 (14.6) |
| Kebede et al., 2016[52] | A.A Abattoir Enterprise | Not stated | Meat | 280 | 13 (4.64) |
| Hunduma et al., 2019[40] | Borana Southern Ethiopia | S.R | Milk | 150 | 7 (4.7) |

A.A: Addis Ababa, S.R: Simple Random, Sy.R: Systematic Random, S.E: South Ethiopia, HU: Haramaya University

Table 3: Subgroup pooled prevalence of Salmonella among Human stools in Ethiopia, (n=34)

| Subgroup analysis by | Number of included studies | Pooled prevalence with (95% CI) |
|----------------------|-----------------------------|--------------------------------|
| Study participants   |                             |                                |
| Children             | 5                           | 4.7 (2.9,7.6)                  |
| Food handlers        | 13                          | 3.7 (2.65,1)                  |
| Outpatients          | 8                           | 7.6 (5.3,10.7)                |
| U5 children          | 8                           | 3.9 (2.3,6.6)                 |
| Location/Direction of the country |       |                                |
| Central Ethiopia     | 8                           | 5.2 (3.9,6.8)                |
| Eastern Ethiopia     | 3                           | 7 (2.7,16.9)                 |
| Northern Ethiopia    | 9                           | 2.6 (1.5,4.4)                |
| Southern Ethiopia    | 13                          | 5.6 (4.1,7.8)                |
| Year of study        |                             |                                |
| 2010–2015            | 12                          | 4.3 (2.8,6.5)                |
| 2015–2020            | 22                          | 5 (3.9,6.3)                  |

The highest pooled prevalence was detected in northern Ethiopia which was 10.2% (95% CI: 6.7, 15.3) followed by southern Ethiopia, 8% (95% CI: 3.4, 17.8) and central Ethiopia, 6.8% (95% CI: 3.7, 12.2). Pooled estimates for western and eastern Ethiopia were not calculated due to the absence/inadequate articles (no study in western and one study in eastern Ethiopia).

Secondary outcome measures

Antimicrobial resistance patterns of Salmonella isolated from both human stools and animal origin foods

The Salmonella isolates showed different antimicrobial resistance profiles against selected agents. The meta-analysis revealed a high-pooled resistant level of Salmonella that was 80.6% (95% CI 72.6, 86.7) resistance for ampicillin and 63.5% (95% CI 53.7, 72.4) for tetracycline with F values of the Logit event estimates. With regard to the year of study, the prevalence of Salmonella in animal origin foods was 8.5% (95% CI: 5.1, 14) in meat, 7.9% (95% CI: 3.8, 15.7) in egg, and 6.7% (95% CI: 3.7, 11.9) in milk with F values of the Logit event estimates in egg, meat, and milk were 92.43%, 88.58%, and 92.53%, respectively (P = 0.000). The subgroup analysis based on animal origin foods indicated that pooled prevalence was 8.5% (95% CI: 5.1, 14) in meat, 7.9% (95% CI: 3.8, 15.7) in egg, and 6.7% (95% CI: 3.7, 11.9) in milk with F values of the Logit event estimates in egg, meat, and milk were 92.43%, 88.58%, and 69.15%, respectively (P = 0.000). With regard to the year of study, the prevalence of Salmonella in animal origin foods was 8.5% (95% CI: 5, 14.1) and 7% (95% CI: 4.6, 10.5) in studies that were published from 2010 to 2015 and 2015 to 2020, respectively. The F values of the Logit event estimates in the 2010–2015 and 2015–2020 were 91.23% and 87.49%, respectively (P = 0.000) [Table 4].
low pooled resistance pattern was reported in ciprofloxacin, 8.7% (95% CI: 5.6, 13.3), ceftriaxone 12.2% (95% CI: 7.9, 18.3), gentamycin 19.6% (95% CI: 13.3, 27.9), and chloramphenicol 35.6% (95% CI: 26.9, 45.2) [Table 5] with $I^2$ values of the Logit event estimates of 47.72%, 46.02%, 65.43%, and 74.87%, respectively.

**Discussion**

We used a systematic method to identify articles reporting the prevalence and antimicrobial resistance profile of *Salmonella* in human stools and animal origin foods in Ethiopia. A total of 49 original articles, 33 of them on human stools, 15 of them on animal origin foods, and 1 on both, were included in this systematic review and meta-analysis to determine the pooled prevalence of *Salmonella* and its antimicrobial resistance status. All the included articles were cross-sectional study design in study type.

In this meta-analysis, the pooled prevalence of *Salmonella* among human stools was 4.8% (95% CI: 3.9, 5.9). A similar study in the Middle Eastern and Northern Africa reported higher pooled *Salmonella* prevalence which was 6.6% (95% CI: 5.4–7.9%). Moreover, higher pooled prevalence reports were reported in Morocco, 17.9% (95% CI: 5.7–34.8%), Tunisia 10.2% (95% CI: 4.3–18.0%), and Sudan 9.2% (95% CI: 6.5–12.2%). However, lower than current pooled prevalence reports were reported from Jordan 1.1% (95% CI: 0.1–3.0%), Oman 1.2% (95% CI: 1.2–1.3%), and Palestine, 1.2% (95% CI: 0.4–2.1%).[65]

The subgroup analysis based on study populations reported the highest pooled prevalence among outpatients which was 7.6% (95% CI: 5.3, 10.7) followed by children, 4.7% (95%...
Ciprofloxacin & 32 & 623 & 49 & 8.7 (5.6, 13.3) 
Tetracycline & 28 & 548 & 373 & 63.5 (53.7, 72.4) 
Ampicillin & 33 & 588 & 477 & 80.6 (72.6, 86.7) 
Ceftriaxone & 25 & 508 & 61 & 12.2 (7.9, 18.3) 
Chloramphenicol & 31 & 660 & 277 & 35.6 (26.9, 45.2) 
Gentamycin & 28 & 499 & 111 & 19.6 (13.3, 27.9) 

Figure 4: Funnel plot for the prevalence of Salmonella among human stools and animal origin foods in Ethiopia

CI: 2.9, 7.6), under-five children, 3.9% (95% CI: 2.3, 6.6), and food handlers, 3.7% (95% CI: 2.6, 5.1). This indicates a higher prevalence of Salmonella in general outpatients than children in contrast to another study which stated higher occurrence of Salmonellosis in diarrheic children, 9.97% (95% CI: –0.41, 20.36) compared to diarrheic adults, 8.22% (95% CI: 5.75, 10.69). This might be due to more raw animal origin food consumption by adults than children in the country.

The pooled prevalence of Salmonella in outpatients attending different health facilities in Ethiopia was 7.6% (95% CI: 5.3, 10.7). In line with this, other studies in Ethiopia which were conducted from 1974 to 2010 reported a similar pooled prevalence was 8.22% (95%, CI: 5.75, 10.69). The present study reported pooled prevalence of Salmonella in children less than fifteen was 4.7% (95% CI: 2.9, 7.6) and in under five age children was 3.9% (95% CI: 2.3, 6.6) which is less than pooled prevalence reported by Tadesse which was 9.97% (95% CI: –0.41, 20.36). This less pooled prevalence in the current study might be due to increased awareness about hygiene and health information dissemination by health extension works mainly by focusing on children to decrease children morbidity and mortality due to diarrhea.

In the current study, subgroup analysis showed pooled prevalence of 3.7% (95% CI: 2.6, 5.1) among food handlers. In support of this report, a study in the Middle Eastern and northern Africa reported similar pooled Salmonella prevalence which was 3.8% (95% CI: 1.0–8.0%) among food handlers. However, other studies in Ethiopia reported lower pooled Salmonella prevalence among food handlers was 1.09% (95% CI: 0.73, 1.44). This might be due to the current high workload for food handlers due to high population growth result in high customers which in turn affect their hygiene by affecting the environmental sanitation including toilet hygiene which increase the exposure of food handlers to pathogen including Salmonella.

The analysis of 16 studies showed that the pooled prevalence of Salmonella in animal origin foods in Ethiopia was 7.7% (95% CI: 5.6, 10.4). The subgroup analysis based on animal origin foods indicated that pooled prevalence was 8.5% (95% CI: 5.1, 14) in meat, 7.9% (95% CI: 3.8, 15.7) in egg, and 6.7% (95% CI: 3.7, 11.9) in milk. Similar pooled prevalence was reported by Zelalem’s study on meat and meat products which was 9% (95% CI: 6.0, 12.0). This result is also in line with a study in Portugal where the prevalence of Salmonella spp. in meats was 6% (95% CI: 4, 9%). However, lower prevalence was reported by the study conducted on ground beef in the United States was 1.9%. This difference might be due to poor food handling practice, lack of slaughtering facility and poor animal health management at primary production, and substandard transport of animal meat contribute to the high prevalence Salmonella pathogen in animal origin foods in Ethiopia.

The subgroup analysis indicated highest pooled prevalence in northern Ethiopia which was 10.2% (95% CI: 6.7, 15.3) followed by southern Ethiopia, 8% (95% CI: 3.4, 17.8), central Ethiopia, 6.8% (95% CI: 3.7, 12.2), and 7% (95% CI: 2.7, 16.9) in eastern Ethiopia among animal origin foods, and 5.6% (95% CI: 4.1, 7.8) in southern Ethiopia, 5.2% (95% CI: 3.9, 6.8) in central Ethiopia, and 2.6% (95% CI: 1.5, 4.4) among human stools. This variation might be due to the difference in basic environmental conditions, behavioral characteristics of animal caregivers, the sociodemographic, environmental, and behavioral characteristics of households.

The pooled prevalence of Salmonella was 4.3% (95% CI: 2.8, 6.5) in human stools and 8.5% (95% CI: 5, 14.1) in animal origin foods from studies published from 2010 to 2015 and 5% (95% CI: 3.9, 6.3) in human stools and 7% (95% CI: 4.6, 10.5) in animal origin foods in studies that were published from 2015 to 2020. This slight difference indicates that no improvements in hygienic and sanitary measures practiced since 2010 might have not reduced the occurrence of Salmonella infections.
Moreover, the slight increases in infections in humans reflect the absence of substantial improvements in the hygienic and sanitary practices of the general population in proportion to population growth.

This meta-analysis also revealed the high-pooled resistant level of *Salmonella* that was 80.6% (95% CI 72.6, 86.7) for ampicillin and 63.5% (95% CI 53.7, 72.4) for tetracycline. However, low pooled resistance pattern was reported in ciprofloxacin, 8.7% (95% CI 5.6, 13.3), ceftriaxone 12.2% (95% CI 7.9, 18.3), gentamycin 19.6% (95% CI 13.3, 27.9), and chloramphenicol 35.6% (95% CI 26.9, 45.2). In contrast to this study, other studies detected 12–63% *Salmonella* resistance to ciprofloxacin and 16.2–49.1% *Salmonella* resistance to ampicillin. In our study, higher and lower prevalence of *Salmonella* resistance to ampicillin and ciprofloxacin, respectively, than other systematic reviews done elsewhere from 2000 to 2017 was reported. In line with the present study, another study reported high resistance, which is 100% resistance to ampicillin, but unlike the present study, high (100%) to ceftriaxone was reported.

However, systematic review by Zelalem et al. reported <10% antimicrobial resistance profile of bacteria by the majority of estimates which is less than the report of the current study which reported 80.6% (95% CI 72.6, 86.7) *Salmonella* resistance against ampicillin. Other systematic reviews also reported less (0–52%) *Salmonella* resistance against ampicillin than the current systematic review and meta-analysis. This study also reported 0–9.25% resistance of *Salmonella* isolates against chloramphenicol, which is less than a report from our systematic review and meta-analysis which reported, 35.6% (95% CI 26.9, 45.2).

The increase in the resistance to the antimicrobial agents in this review and meta-analysis in comparison to other studies could be associated with extensive use of antimicrobials not only as therapeutic agents for human infections but also for prophylaxis and growth promotion in animal husbandry. The driving force behind the increasing rates of resistance of *Salmonella* to antimicrobial agents both in human and animals can ultimately be found in the abuse and misuse of antibacterial agents in patients/livestock and releasing into the environment and also inappropriate use of antibiotics, inadequate infection prevention and control programs, limited laboratory capacity, poor surveillance, population growth, and migration, as well as inadequate sanitation. Moreover, the high resistance to ampicillin and tetracycline in this review may be due to easily availability of these drugs and widely usage of it in both human and veterinary medicine.

**Strength and limitation**

This study has the following strengths; it is the first systematic review and meta-analysis conducted in Ethiopia to show the national pooled prevalence and antimicrobial resistance profiles of *Salmonella* isolates in both human stools and animal origin foods. The reviewed articles have the same study design and the same laboratory method used to isolate the pathogen and assess the antimicrobial resistance. It has analyzed articles from most parts of the country where eligible studies have been retrieved from by comprehensive research strategy. It has included many articles conducted for more than 10 years that will enable the reader to understand the trend changing with time. The subgroup analysis was conducted. Nevertheless, this study has limitations such as studies included for analysis were heterogeneous as some were done in food handlers, outpatients, different age group children, and different types of animal foods (milk, meat, and egg) and also there was some sort of publication bias. No study from western Ethiopia was found to include in subgroup analysis.

**Conclusion and Recommendation**

The pooled prevalence of *Salmonella* among human stools and animal origin foods in Ethiopia was 4.8% (95% CI: 3.9, 5.9) and 7.7% (95% CI: 5.6, 10.4), respectively. The subgroup analysis detected higher pooled prevalence among outpatients, 7.6% (95% CI: 5.3, 10.7) than pooled prevalence among children, 4.7% (95% CI: 2.9, 7.6), and under-five children, 3.9% (95% CI: 2.3, 6.6), whereas lower prevalence among food handlers, 3.7% (95% CI: 2.6, 5.1). Higher and lower pooled prevalence also was reported eastern Ethiopia 7% (95% CI: 2.7, 16.9) and central Ethiopia 2.6% (95% CI: 1.5, 4.4), respectively, in human stools, but in northern Ethiopia which was 10.2% and Central Ethiopia, 6.8% (95% CI: 3.7, 12.2) in case of animal origin foods. The subgroup analysis based on animal origin foods indicated that pooled prevalence was 8.5% (95% CI: 5.1, 14) in meat, 7.9% (95% CI: 3.8, 15.7) in egg, and 6.7% (95% CI: 3.7, 11.9) in milk. The prevalence of *Salmonella* in animal origin foods was higher in studies published from 2010 to 2015, 8.5% (95% CI: 5, 14.1) compared to those published from 2015 to 2020, 7% (95% CI: 4.6, 10.5).

The pooled resistant level of *Salmonella* was 80.6% (95% CI 72.6, 86.7) resistance for ampicillin and 63.5% (95% CI 53.7, 72.4) for tetracycline, respectively. However, low pooled resistance pattern was reported in ciprofloxacin, 8.7% (95% CI 5.6, 13.3), ceftriaxone 12.2% (95% CI 7.9, 18.3), gentamycin 19.6% (95% CI 13.3, 27.9), and chloramphenicol 35.6% (95% CI 26.9, 45.2). This systematic review and meta-analysis showed ciprofloxacin, ceftriaxone gentamycin, and slightly chloramphenicol is effective, but ampicillin and tetracycline are ineffective. It is clear that the *Salmonella* disease burden is of public and economic importance. Therefore, routine diagnosis of *Salmonella*, appropriate use of antimicrobials based on laboratory result, educating communities on hygienic practices and animal/food handle and use, and antimicrobial resistance surveillance system is necessary to reduce both the *Salmonella* prevalence and antimicrobial resistance in Ethiopia.
**Authors’ Declaration Statements**

**Ethical approval and patients consent**
Not applicable since this study is a systematic review and meta-analysis where possible to get study participants to consent, moreover no individual’s information to be exposed.

**Availability of data and material**
The data used in this study are available and will be provided by the corresponding author on a reasonable request.

**Competing interest**
The authors declare that they have no competing interests.

**Funding statement**
None.

**Authors’ Contributions**
DA and NA conceived and designed the study. Both authors collected scientific literature, critically appraised individual articles for inclusion, analyzed, and interpreted the findings. DA drafted the manuscript, critically reviewed it, and prepared the final version for publication. Both authors read and approved the final version.

**Acknowledgment**
Authors thank Shifera Leta, Mekonnen Sisay, and Jemal Yusuf for guiding/helping me in preparation of this document and helping us in searching articles from the Embase database and also authors of articles that were used in this review and meta-analysis.

**References**

1. Andrews AH, Blowey R, Eddy RG, Boyd H. Bovine Medicine: Diseases and Husbandry of Cattle. United States: John Wiley & Sons; 2008.
2. Heredia NL, Wesley IV, Garcia JS. Microbiologically Safe Foods. United States: John Wiley & Sons; 2009.
3. Hoffman S, Maculloch B, Batz M. Economic Burden of Major Foodborne Illnesses Acquired in the United States. United States Department of Agriculture, Economic Information Bulletin; 2015.
4. Gould G, Russell N. Major, New, and Emerging Food-poisoning and Food-spoilage Microorganisms, in Food Preservatives. Berlin, Germany: Springer; 2010.
5. Le Hello S, Harrois D, Bouchrif B, Sontag L, Elhani D, Guibert V, et al. Highly drug-resistant Salmonella enterica serotype kentucky st198-x1: A microbiological study. Lancet Infect Dis 2013;13:672-9.
6. Kariuki S, Revathi G, Kariuki N, Muyodi J, Mwituria J, Munyalo A, et al. Increasing prevalence of multidrug-resistant non-typhoidal salmonellae, Kenya, 1994-2003. Int J Antimicrob Agents 2005;25:38-43.
7. Niehaus AJ, Apalata T, Coovadia YM, Smith AM, Moodley P. An outbreak of foodborne salmonellosis in rural Kwazulu-Natal, South Africa. Foodborne Pathog Dis 2011;8:693-7.
8. Angulo FJ, Molk B. Human health consequences of antimicrobial drug-resistant Salmonella and other foodborne pathogens. Clin Infect Dis 2005;41:1613-20.
9. Getachew M, Mulugeta G, Lema T, Aseffa A. Prevalence and antimicrobial susceptibility patterns of Salmonella serovars and Shigella species in Butajira, Central Ethiopia. J Micro Biochem Technol 2014;6:S2-006.
10. World Health Organization. Foodborne Disease Outbreaks: Guidelines for Investigation and Control. Geneva: World Health Organization; 2008.
11. Bayeh A, Fantahun B, Belaye B. Prevalence of Salmonella typhi and intestinal parasites among food handlers in Bahir Dar town, Northwest Ethiopia. EJHD 2010;24:46-50.
12. Hutton B, Catala-Lopez F, Moher D. The prisma statement extension for systematic reviews incorporating network meta-analysis: Prismanma. Med Clin 2016;147:262-6.
13. Patel J, Cockerill F, Bradford P. M100-s24 Performance Standards for Antimicrobial Susceptibility Testing. Twenty-fourth Informational Supplement. London, United Kingdom: Clinical and Laboratory Standards Institute; 2014.
14. London S, Gurdal O, Gall C. Automatic export of pubmed® citations to endnote®. Med Ref Serv Quart 2010;29:146-53.
15. Schulz T, Florence Z. Joanna Briggs Institute Meta-analysis of Statistics Assessment and Review Instrument. Adelaide: Joanna Briggs Institute; 2007.
16. Abebe W, Earsido A, Taye S, Assefa M, Eysau A, Godebo G. Prevalence and antibiotic susceptibility patterns of Shigella and Salmonella among children aged below five years with diarrhea of the southern Ethiopia. BMC Microbiol 2018;18:241-1.
17. Ameya G, Tsalla T, Getu F, Getu E. Antimicrobial susceptibility pattern, and associated factors of Salmonella and Shigella infections among under children in Arba Minch, South Ethiopia. Ann Clin Microbiol Antimicrob 2018;17:1.
18. Assefa A, Girma M. Prevalence and antimicrobial susceptibility patterns of Salmonella and Shigella isolates among children aged below five years with diarrhoea attending nigit eleni mohammed memorial hospital, South Ethiopia. BMC Pediatr 2018;18:241-1.
19. Felleke H, Medhin G, Abebe A, Beyene B, Kloos H, Asrat D. Enteric pathogens and associated risk factors among under-five children with and without diarrhea in Wegera district, Northwestern Ethiopia. Pan Afr Med J 2018;29:72.
20. Getamesay M, Getenet B, Ahmed Z. Prevalence of Shigella, Salmonella and Campylobacter species and their susceptibility patters among under five children in Hawassa town, South Ethiopia. Ethiop J Health Sci 2014;24:101-8.
21. Mamuye Y, Amaru GM, Mekonnen AB, Desta K, Fantaw S. Isolation and antibiotic susceptibility patterns of Shigella and Salmonella among under 5 children with acute diarrhoea: A cross-sectional study at selected public health facilities in Addis Ababa, Ethiopia. J Clin
Abate and Assefa: Patterns of Salmonella in Ethiopia

Microbiol 2015;2015:1000186.

25. Tosisa W, Mihret A, Ararsa A, Eguale T, Abebe T. Prevalence and antimicrobial susceptibility of Salmonella and Shigella species isolated from diarrheic children in ambo town. BMC Pediatr 2020;20:91.

26. Yemane G, Mulam G, Gaim T. Prevalence and antimicrobial susceptibility of Salmonella species in diarrheal children under five-years of age in Bahir Dar town, Ethiopia. Int J Int Sci Inn Tech Sec A 2014;3:12-7.

27. Aklilu A, Kahase D, Dessalegn M, Tarekegn N, Gebremichael S, Zenebe S, et al. Prevalence of intestinal parasites, Salmonella and Shigella among apparently healthy food handlers of Addis Ababa university student’s Cafeteria, Addis Ababa, Ethiopia. BMC Res Notes 2015;8:17.

28. Aowel N, Nigusse D, Ali M. Prevalence and antimicrobial susceptibility pattern of Salmonella and Shigella among food handlers working in food establishment at Hawassa city, Southern Ethiopia. BMC Res Notes 2019;12:1-7.

29. Bafa TA, Sherif EM, Hantalo AH, Woldeamanuel GG. Magnitude of enteropathogens and associated factors among apparently healthy food handlers at wolkite university student’s Cafeteria, Southern Ethiopia. BMC Res Notes 2019;12:567.

30. Garedew L. Identification of drug-resistant Salmonella from food handlers at the university of Gonder, Ethiopia. BMC Res Notes 2014;7:545.

31. Gebreyesus A, Adane K, Welekidan LN, Dejene TA, Belay S, Alemu M, et al. Prevalence of Salmonella typhi and intestinal parasites among food handlers in mekelle university student Cafeteria, Mekelle, Ethiopia. Food Control 2014;44:45-8.

32. Getie M, Abebe W, Tessema B. Prevalence of enteric bacteria and their antimicrobial susceptibility patterns among food handlers in Gondar town, Northwest Ethiopia. Antimicrob Resist Infect Control 2019;8:111.

33. Getnet F, Awulachew E, Ashuro Z. Prevalence and antimicrobial resistance of Salmonella isolated from food handlers in addis ababa university students’ cafeterias, Ethiopia. Afr J Basic Appl Sci 2014;6:210-6.

34. Mama M, Alemu G. Prevalence, antimicrobial susceptibility patterns and associated risk factors of Shigella and Salmonella among food handlers in Arba Minch university, South Ethiopia. BMC Infect Dis 2016;16:686.

35. Marami D, Hailu K, Tolea M. Prevalence and antimicrobial susceptibility pattern of Salmonella and Shigella species among asymptomatic food handlers working in Haramaya university cafeterias, Eastern Ethiopia. BMC Res Notes 2018;11:74.

36. Solomon FB, Wada FW, Anjulo AA, Koyra HC, Tufa EG. Burden of intestinal pathogens and associated factors among asymptomatic food handlers in South Ethiopia: Emphasis on salmonellosis. BMC Res Notes 2018;11:502.

37. Tadesse G, Mitiku H, Teklemaryam Z, Marami D. Salmonella and Shigella among asymptomatic street food vendors in the Dire Dawa city, Eastern Ethiopia: Prevalence, antimicrobial susceptibility pattern, and associated factors. Environ Health Insights 2019;13:1-8.

38. Yesigat T, Jemal M, Birhan W. Prevalence and associated risk factors of Salmonella, Shigella, and intestinal parasites among food handlers in Motta town, north West Ethiopia. CJHD 2020;2020:6425946.

39. Adimasu DA, Kebede A, Menkir S, Abubeke R, Miher A, Fantaw S, et al. Prevalence of antibiotic resistant Salmonella species and selected intestinal protozoan parasites in Harar Hiwot Fana hospital, Ethiopia. Am J Biochem Mol Bio 2014;4:99-111.

40. Demissie A. Prevalence and antimicrobial susceptibility patterns of Shigella and Salmonella species among patients with diarrhea attending Gondar town health institutions, Northwest Ethiopia. Sci J Public Health 2014;2:469-75.

41. Eguale T, Gebreyes WA, Asrat D, Alemayehu H, Gunn JS, Engidawork E. Non-typhoidal salmonellosis, antimicrobial resistance and co-infection with parasites among patients with diarrhea and gastroenteritis in Addis Ababa, Ethiopia. Trop Med Int Health 2015;20:S1-263.

42. Endalu M. Occurrence of Salmonella in Selected Beef Chain Locations and Stool of Diarrheic Patients in Adama, Ethiopia. Assam: AAU Institutional Repository; 2019.

43. Lamboro T, Ketema T, Bacha K. Prevalence and antimicrobial resistance in Salmonella and Shigella species isolated from out patients, Jimma university specialized hospital, Southwest Ethiopia. AJBAS 2017;9:118-25.

44. Terafssa A, Jida M. Prevalence and antibiotics susceptibility pattern of Salmonella and Shigella species among diarrheal patients attending nekemte referral hospital, Oromia, Ethiopia. Int J Microbiol 2018;2018:6.

45. Teshome B, Teklemariam Z, Ayana DA, Marami D, Asaminew N. Salmonella and Shigella among patients with diarrhea at public health facilities in Adama, Ethiopia: Prevalence, antimicrobial susceptibility pattern, and associated factors. SSAGE Open Med 2019;7:1-8.

46. Beyene G, Nair S, Asrat D, Mengistu Y, Engers H, Wain J. Multidrug resistant Salmonella concord is a major cause of salmonellosis in children. J Infect Dev 2011;5:23-33.

47. Beyene G, Tassew H. Prevalence of intestinal parasite, Shigella and Salmonella species among diarrheal children in Jimma health center, Jimma Southwest Ethiopia: A cross sectional study. Ann Clin Microbiol Antimicrob 2014;13:10.

48. Gebrezgiabher G, Asrat D, Amanuel YW, Hagos T. Isolation and antimicrobial susceptibility profile of Shigella and Salmonella species from children with acute diarrhoea in mekelle hospital and semen health center, Ethiopia. Ethiop J Health Sci 2018;28:197-206.

49. Hayamo M, Alemayehu T, Tadesse B, Mitiku E, Bedawi Z. Shigella and Salmonella, Antibiotics Susceptibility Pattern and Associated Risk Factors Among Diarrheic Children in Southern Ethiopia: A Cross Sectional Study. Washington, DC: Research Square; 2019.

50. Abebe M, Tafese B, Adane H. Antimicrobial resistance of Salmonella serovars isolated from food of bovine origin in selected woredas of Tigray, Ethiopia. World J Med Sci 2014;11:342-7.

51. Asfaw Ali D, Tadesse B, Ebabu A. Prevalence and antibiotic resistance pattern of salmonella isolated from caecal contents of exotic chicken in Debre Zeit and Modjo. Ethiopia. Int J Microbiol 2020;2020:1910630.

52. Kebede A, Kemal J, Alemayehu H, Mariam SH. Isolation, identification, and antibiotic susceptibility testing of Salmonella from slaughtered bovines and ovines in Addis Ababa abattoir enterprise, Ethiopia: A cross-sectional study. Int J Bacteriol 2016;2016:3714785.

53. Mengistu S, Abayneh E, Shiferaw D, Coli E. o157: H7 and Salmonella species isolated from out patients, Jimma university specialized hospital, Southwest Ethiopia. AJBAS 2015;2015:1000186.

54. Zelalem S. Assessment of the Contamination of Beef with Salmonella and Shigella species among diarrheal patients attending nekemte referral hospital, Oromia, Ethiopia. Am Euro J Agric Environ Sci 2011;11:512-8.

55. Taddese D, Tolosa T, Gelalcha BD, Jakow M, Olani, A, Shumi E. Antibiograms and risk factors of Salmonella isolates from laying hens and eggs in Jimma town, South Western Ethiopia. BMC Res Notes 2019;12:472.

56. Tsegaye S, Beyene W, Birhanu BT, Tessema TS, Fefeke A, et al. Non-typhoidal salmonellosis, antimicrobial resistance and co-infection with parasites among patients with diarrhea and gastroenteritis in Addis Ababa, Ethiopia. Trop Med Int Health 2015;20:S1-263.
Prevalence and antimicrobial susceptibility pattern of *Salmonella* species from exotic chicken eggs in alage, Ziway and Shashemene, Ethiopia. Afr J Basic Appl Sci 2016;8:180-4.

58. Abate AA, Rakshit SK, Anal AK. Genotypic and phenotypic characterization of antimicrobial resistance patterns of *Salmonella* strains isolated from raw milk in Sebeta, Ethiopia. Int J Adv Life Sci 2013;6:192-9.

59. Addis Z, Kebede N, Worku Z, Gezahegn H, Yirsaw A, Kassa T. Prevalence and antimicrobial resistance of *Salmonella* isolated from lactating cows and in contact humans in dairy farms of Addis Ababa: A cross sectional study. BMC Infect Dis 2011;11:222.

60. Hunduma D, Alonso S, Agga G, Kerro O, Wieland B, Desta H, et al. Occurrence and Antimicrobial Resistance Patterns of *Escherichia coli* o157: H7 and Non-typhoid *Salmonella* in Milk and Feces of Lactating Dairy Cows and Camels in Borana, Southern Ethiopia. United States: IAFP; 2019. p. P2-249.

61. Ejo M, Garedew L, Alebachew Z, Worku A. Prevalence and antimicrobial resistance of *Salmonella* isolated from animal-origin food items in Gondar, Ethiopia. Biomed Res Int 2016;2016:4290506.

62. Mulaw G. Prevalence and antimicrobial susceptibility of *Salmonella* species from lactating cows in dairy farm of bahir dar town, Ethiopia. J Microbiol Res 2017;11:1578-85.

63. Tadesse T, Dabassa A. Prevalence and antimicrobial resistance of *Salmonella* isolated from raw milk samples collected from Kersa district, Jimma zone, Southwest Ethiopia. J Med Sci 2012;12:224-8.

64. Tesfaw L, Taye B, Alemu S, Alemayehu A, Sisay Z, Negussie H. Prevalence and antimicrobial resistance profile of *Salmonella* isolates from dairy products in Addis Ababa, Ethiopia. Afr J Microbiol Res 2013;7:5046-50.

65. Al-Rifai RH, Chaabna K, Denagamage T, Alali WQ. Prevalence of enteric non-typhoidal *Salmonella* in humans in the Middle East and North Africa: A systematic review and meta-analysis. Zoonoses Public Health 2019;66:701-28.

66. Tadesse G. Prevalence of human salmonellosis in Ethiopia: A systematic review and meta-analysis. BMC Infect Dis 2014;14:88.

67. Crump JA, Sjölund-Karlsson M, Gordon MA, Parry CM. Epidemiology, clinical presentation, laboratory diagnosis, antimicrobial resistance, and antimicrobial management of invasive *Salmonella* infections. Clin Microbiol Rev 2015;28:901-37.

68. Zelalem A, Sisay M, Vipharm JL, Abegaz K, Kebede A, Terefe Y. The prevalence and antimicrobial resistance profiles of bacterial isolates from meat and meat products in Ethiopia: A systematic review and meta-analysis. Int J Food Contam 2019;6:1.

69. Xavier C, Gonzales-Barron U, Paula V, Estevinho LM. Meta-analysis of the incidence of foodborne pathogens in portuguese meats and their products. Food Res Int 2014;55:311-23.

70. US Department of Agriculture, Forest Service and Interior Service. Progress Report on *Salmonella* and Campylobacter Testing of Raw Meat and Poultry Products, 1998-2013. United States: US Department of Agriculture, Forest Service and Interior Service; 2014.

71. Britto CD, Wong VK, Dougan G, Pollard AJ. A systematic review of antimicrobial resistance in *Salmonella enterica* serovar typhi, the etiological agent of typhoid. PLoS Negl Trop Dis 2018;12:e0006779.

72. Tadesse G. A meta-analysis of the proportion of animal *Salmonella* isolates resistant to drugs used against human salmonellosis in Ethiopia. BMC Infect Dis 2015;15:84.