



Systematic literature review of *Salmonella* and *Campylobacter* in chicken meat and enterotoxigenic *Escherichia coli* and *Salmonella* in vegetables in Ethiopia and Burkina Faso



CGIAR

RESEARCH PROGRAM ON
Agriculture for
Nutrition
and Health

BILL & MELINDA
GATES *foundation*



Systematic literature review of *Salmonella* and *Campylobacter* in chicken meat and enterotoxigenic *Escherichia coli* and *Salmonella* in vegetables in Ethiopia and Burkina Faso

Lina Gazu¹, Filipe Maximiano², Pattama Ulrich³, Tadesse Guadu⁴, Delia Grace^{1,5}, Silvia Alonso¹, Florence Mutua¹, Kristina Roesel¹, Johanna Lindahl¹, Kebede Amenu⁶, Guy Ilboudo¹, Michel Dione¹ and Theo Knight-Jones¹

1 International Livestock Research Institute

2 University of Bern, Switzerland

3 University of Gondar, Ethiopia

4 Ohio State University, USA

5 Natural Resources Institute, University of Greenwich, UK

6 Addis Ababa University, Ethiopia

December 2021

©2021 International Livestock Research Institute (ILRI)

ILRI thanks all donors and organizations which globally supports its work through their contributions to the CGIAR Trust Fund



This publication is copyrighted by the International Livestock Research Institute (ILRI). It is licensed for use under the Creative Commons Attribution 4.0 International Licence. To view this licence, visit <https://creativecommons.org/licenses/by/4.0>. Unless otherwise noted, you are free to share (copy and redistribute the material in any medium or format), adapt (remix, transform, and build upon the material) for any purpose, even commercially, under the following conditions:



ATTRIBUTION. The work must be attributed, but not in any way that suggests endorsement by ILRI or the author(s).

NOTICE:

For any reuse or distribution, the licence terms of this work must be made clear to others.

Any of the above conditions can be waived if permission is obtained from the copyright holder.

Nothing in this licence impairs or restricts the author's moral rights.

Fair dealing and other rights are in no way affected by the above.

The parts used must not misrepresent the meaning of the publication.

ILRI would appreciate being sent a copy of any materials in which text, photos etc. have been used.

Editing, design and layout—ILRI Editorial and Publishing Services, Addis Ababa, Ethiopia.

Cover photo—ILRI/Bettridge

ISBN: 92-9146-689-0

Citation: Gazu, L., Maximiano, F., Ulrich, P., Guadu, T., Grace, D., Alonso, S., Mutua, F. Roesel, K., Lindahl, J., Amenu, K., Ilboudo, G., Dione, M. and Knight-Jones, T. 2021. *Systematic literature review of Salmonella and Campylobacter in chicken meat and enterotoxigenic Escherichia coli and Salmonella in vegetables in Ethiopia and Burkina Faso*. ILRI Research Report 90. Nairobi, Kenya: ILRI.

Patron: Professor Peter C. Doherty AC, FAA, FRS

Animal scientist, Nobel Prize Laureate for Physiology or Medicine—1996

Box 30709, Nairobi 00100 Kenya
Phone +254 20 422 3000
Fax+254 20 422 3001
Email ilri-kenya@cgiar.org

ilri.org
better lives through livestock
ILRI is a CGIAR research centre

Box 5689, Addis Ababa, Ethiopia
Phone +251 11 617 2000
Fax +251 11 667 6923
Email ilri-ethiopia@cgiar.org

ILRI has offices in East Africa • South Asia • Southeast and East Asia • Southern Africa • West Africa

Contents

Tables	v
Figures	vi
Acknowledgements	vii
Executive summary	viii
1 Introduction	1
2 Review methodology	2
2.1 Initial review of all foodborne disease hazards	2
2.2 Search strategy	2
2.3 Inclusion and exclusion criteria	2
2.4 Study selection process and data extraction	3
2.5 Data extraction for specific hazard–commodity combinations	3
3 Results	4
3.1 Search result	4
3.2 Chicken value chain	5
3.2.1 <i>Salmonella</i> spp in chicken value chain	5
3.2.2 <i>Campylobacter</i> in chicken value chain	6
3.3 Vegetable value chain	7
3.3.1 ETEC in vegetables	7
3.3.2 <i>Salmonella</i> in vegetable samples	7
3.4 Characterization of bacterial serotypes and species	8
3.5 Antimicrobial susceptibility testing	9

4	Discussion	11
	4.1 Chicken value chains	11
	4.2 Vegetable value chains	12
	4.3 Identification of species and serotypes	12
	4.4 Antimicrobial resistance	13
	4.5 Gaps in evidence	13
5	Conclusion	14
6	References	15
	Appendix A. Systematic literature review search terms used	19
	Appendix B. Summary of studies from Ethiopia and Burkina Faso	20
	Studies with specific hazard–commodity combinations in Ethiopia found in this SLR, 1990–2019	20
	Studies with specific hazard–commodity combinations in Burkina Faso found in this SLR, 1990–2019	21

Tables

Table 1. Number of retained studies with suitable topic focus and quality	5
Table 2. Number of positive samples reported for <i>Salmonella</i> serotypes in Ethiopian chicken meat and gilet samples	8
Table 3. Antibiotic resistance of isolated <i>Salmonella</i> species in vegetable value chains in Ethiopia	10

Figures

- Figure 1. Flowchart of main search strategy and article selection for review of studies for all FBD hazards, then filtering only those reporting *Campylobacter* or NTS in chicken and those reporting NTS or ETEC in vegetables 4
- Figure 2. Comparison of *Salmonella* contamination in gilet and chicken meat samples collected from Ethiopia 6
- Figure 3. Prevalence of NTS in vegetable samples collected from farms and markets in Ethiopia 8

Acknowledgements

This report was produced within the project 'Urban food markets in Africa: Incentivising food safety using a pull-push approach'. The project is supported by the Bill & Melinda Gates Foundation, UK Aid from the UK Foreign, Commonwealth and Development Office, and the CGIAR Research Program on Agriculture for Nutrition and Health led by the International Food Policy Research Institute (IFPRI).

Executive summary

We performed a systematic literature review of studies conducted in Ethiopia and Burkina Faso that identified non-typhoidal *Salmonella* spp (NTS) and *Campylobacter* spp in chicken meat, and enterotoxigenic *Escherichia coli* (ETEC) and *Salmonella* spp in vegetables, published between January 1990 and 30 September 2019 inclusive.

Vegetables and chicken are commonly eaten together and are the focus of the pull-push project¹. We had previously conducted an SLR on foodborne disease hazards and burdens in Ethiopia and Burkina Faso (1990–2019) according to Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines where data were extracted from 142 studies in Ethiopia and 22 studies in Burkina Faso (Lina et al. 2020). From these, 15 papers met the inclusion criteria for this more focussed report. Reference searches identified one additional paper as relevant, yielding a total of 16 papers from which to extract data for this review.

The papers mostly described pathogen prevalence surveys for specific commodities in specific enterprises or sites. In Ethiopia, prevalence of NTS contamination of chicken meat and carcasses was ranged from 8.3–15.4% in samples collected from markets in Addis Ababa and Debre Zeit (four studies with 104–452 samples per study). In Burkina Faso, levels of NTS contamination of chicken carcasses sampled from different markets in Ouagadougou showed much greater variation with prevalence ranging from 37% to 90% (five studies with 20–30 samples per study). The high levels of contamination reflect a general absence of adequate food safety practices along the supply chains. However, the comparability between different studies may be limited, with sampling strategy and laboratory methods having a strong influence on pathogen detection and count.

In Ethiopia, *Campylobacter* was found in 16.7% and 26.7% respectively of the 60 chicken meat samples collected from supermarkets in the capital and an abattoir in an area of commercial livestock production (Debre Zeit). Half (10/20) of the poultry carcass samples from retail markets in Ouagadougou were contaminated with *Campylobacter* spp. However, high levels of *Campylobacter* contamination are also reported in many developed countries. Studies conducted in Ethiopia showed higher *Salmonella* and *Campylobacter* contamination in samples from chicken compared to samples collected from other animals but again, comparability depends on having equivalent sampling, processing and testing systems. The paucity of *Campylobacter* studies in part reflects the challenges of isolating *Campylobacter* spp and the few labs able to do this in Burkina Faso and Ethiopia.

Considering the poor hygiene widely seen in informal poultry slaughter enterprises in the two countries, high levels of bacterial contamination are expected – possibly higher than is reported. These high levels of contamination highlight cross-contamination risks and the need for good hygiene to limit this, and thorough cooking to kill pathogens on the raw products or those acquired through cross-contamination.

The literature from the two countries did not report on ETEC specifically, but half (52.4%) of vegetable salad samples in Ethiopia were positive for *E. coli*, with a study finding about 45% prevalence in cabbage and carrot, versus 20% in

¹Urban food markets in Africa: Incentivizing food safety using a pull-push approach.

tomato, green pepper and lettuce. There were no papers reporting *E. coli* in vegetables in Burkina Faso. A few Ethiopian studies (n=4) found *Salmonella* contamination ranging from 23.9–30% in cabbage and 9–20% in tomato. Contaminated irrigation water is thought to be an issue (23% of water samples were positive for *Salmonella* in Ethiopia). In Burkina Faso, all 32 salad samples collected in a study of street food vendors were negative for *Salmonella*, while 10 of the 20 lettuce samples collected from vegetable farms in Ouagadougou were contaminated with *Salmonella*, again possibly related to irrigation water.

In conclusion, the literature reports high prevalences of *Salmonella* and *Campylobacter* in chicken meat and *E. coli* and *Salmonella* in vegetables in Burkina Faso and Ethiopia, reflecting a high risk of foodborne disease. Coordinated surveillance, improved food safety systems, and better awareness and practices among consumers and value chain actors are needed. Thorough washing and the use of sanitizer chemicals for vegetables, and education of food handlers were recommended in the studies.

The number of high-quality, relevant studies was limited. From those identified most were small, isolated studies focusing on a particular site or location, rather than larger more representative studies, or coordinated research programs providing a strong body of evidence. Both in Burkina Faso and Ethiopia, studies were highly concentrated in the capital cities. Most of these studies focussed on reporting prevalence; risk factors or pathways for contamination along vegetable and chicken value chains were rarely investigated.

The literature leaves us with a limited understanding of the risks, epidemiology and control options for *Campylobacter*, NTS and ETEC along vegetable and chicken value chains in Burkina Faso and Ethiopia. At a more pragmatic level, we do know that food hygiene in these systems is poor, and consequently consumers face a high risk of foodborne disease from widespread pathogens including those studied in this review. With the numbers living in urban Africa continuously growing there an urgent need to improve our understanding of the changing food safety risks in these urban African settings, including evidenced cost-effective approaches to control the massive FBD burden.

1 Introduction

This systematic literature review (SLR) was conducted on four hazard–commodity combinations that play a significant role in FBD: *Campylobacter spp* and non-typhoidal *Salmonella spp* (NTS) in poultry meat; and enterotoxigenic *Escherichia coli* (ETEC) and NTS in vegetables, which are commonly eaten with poultry meat. The four hazard–commodity combinations targeted in the pull-push project² were selected based on evidence from the FBD Burden Epidemiology Reference Group’s Global Burden of FBD estimates (<https://www.foodbornediseaseburden.org>) and a food safety investment study looking at Burkina Faso, Ethiopia and Nigeria (Grace et al. 2018).

Poultry value chains in Ethiopia and Burkina Faso are characterized by traditional production systems, with village chicken production accounting for above 90% of the total chicken production in Ethiopia (Hailemariam et al. 2018), and 80% of households in Burkina Faso owning poultry (Leight and Martinez 2020). Poultry production is often the domain of women (Rota and Sperandini 2010), though men can have a meaningful role in ownership and management when poultry become an important source of household income (Hailemariam et al. 2018; Leight and Martinez 2020).

Common actors involved in vegetable value chains in Ethiopia are input suppliers, producers, brokers, traders (wholesalers and retailers) and consumers (Desalegn 2021). The development of vegetable gardening in Burkina Faso has been largely led by farmers who have made use of opportunities following the increased availability of water and the growing demand for vegetables (Gross and Jaubert 2019).

In both countries food is mostly obtained through informal value chains. Food safety is often poorly regulated with limited regard for food safety. Here we review the published scientific literature in Ethiopia and Burkina Faso on four hazard-commodity combinations, two priority microbial hazards in chicken and two in vegetables, recognising that a few key pathogens account for much of the FBD burden.

²The Pull-Push project ‘Urban food markets in Africa: Incentivizing food safety using a pull-push approach’ is implemented by the International Livestock Research Institute (ILRI) in collaboration with national and international partners in Ethiopia and Burkina Faso.

2 Review methodology

2.1 Initial review of all foodborne disease hazards

Initially an SLR was done for all foods and foodborne pathogens (Lina et al. 2020) addressing the following questions:

- What is the incidence of FBDs in Ethiopia and Burkina Faso?
- What is the health burden associated with FBD in Ethiopia and Burkina Faso?
- What is the prevalence of FBD hazards in water, vegetables, animal source foods and other food products in Ethiopia and Burkina Faso?

The method used is described below.

2.2 Search strategy

We defined a systematic review following methods defined by the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) Statement (Moher et al. 2009). A comprehensive search of PubMed and CAB Direct was performed for publications from 1 January 1990 to 30 September 2019, using a syntax including, but not limited to, the keywords 'foodborne', 'food-borne', 'food safety', 'food related', 'food associated', 'food derived', 'food illness', 'food* intoxication', 'food pathogen', 'food* poisoning', 'microbes', 'food virus', 'food parasites', 'food toxin', 'Ethiopia' and 'Burkina Faso'. The full search terms are documented in Appendix A. The syntax was left generic to capture all literature covering the various aspects of interest (e.g. prevalence, impact, risk factors, control).

2.3 Inclusion and exclusion criteria

Observational studies, secondary data analysis and reviews were included if they reported FBD in the two target countries (Ethiopia and Burkina Faso), in particular the incidence in humans, health burden and prevalence in foods. Search languages were English for both countries and French for Burkina Faso.

Studies focusing exclusively on non-foodborne illness/hazards, laboratory-based studies, and antimicrobial resistance studies were excluded but reports on antimicrobial residues were captured. We also excluded studies not reporting information on disease caused by foodborne (i.e. food/drinks) microbes or toxins, in terms of incidence, health burden or contamination of food products. Thus, studies reporting hazards in, for example, animal faeces, animal serology or carriage in vectors were not included. Studies outside Ethiopia and Burkina Faso and papers on aspects of basic sciences (immunology/molecular biology/physiology) were also excluded.

2.4 Study selection process and data extraction

Upon searching the online databases, full lists of titles and abstracts were downloaded and checked for duplicates using Mendeley (<https://www.mendeley.com>). The titles and abstracts were uploaded to an Excel spreadsheet and screened by two reviewers against inclusion and exclusion criteria. All articles considered relevant by both reviewers were kept; articles considered relevant by just one reviewer were reviewed again by a third reviewer and a decision was made on eligibility.

Full papers from selected titles were obtained when available. Then full articles were subjected to a two-step screening process by a single reviewer. Papers were reviewed against 1) inclusion and 2) quality criteria. The five quality measures used for screening were unbiased selection of subjects, appropriate data analysis, scientifically sound methods, accurate and complete description of methods, and robust analysis and results. For each criterion papers were assigned as adequate or deficient. Article quality was then rated as good, medium or poor as follows: Articles deemed adequate for none, one or two of the five quality criteria were classified as poor; those adequate for three or four criteria were classified as medium; and those adequate for all quality criteria were classified as good. Articles judged as poor quality were excluded. Data were extracted from retained papers using a template.

2.5 Data extraction for specific hazard–commodity combinations

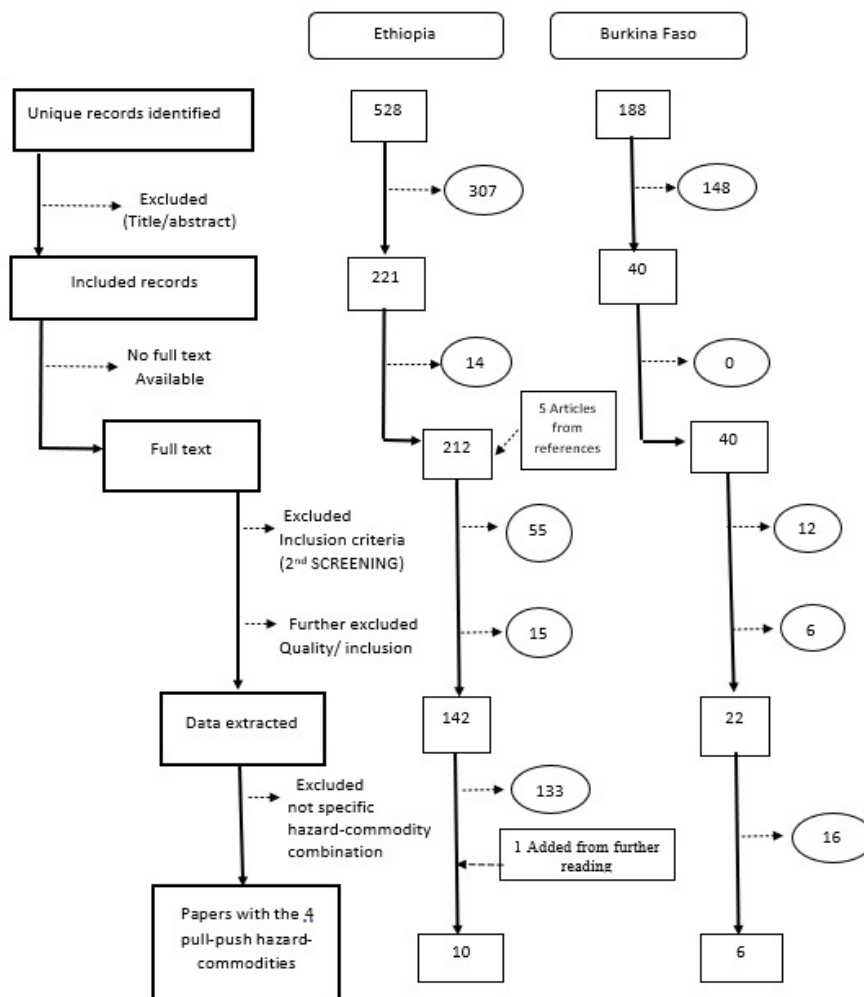
This broader SLR identified the most important foodborne hazards associated with vegetables, animal source foods, water (for drinking or food preparation), and other human food products for all ages in Ethiopia and Burkina Faso according to the reported incidence in humans, health burden and prevalence in foods. This was reported in 2020 as ‘Systematic literature review of foodborne disease hazards and burden in Ethiopia and Burkina Faso 1990–2019, with detailed 2017–19 update’ (Lina et al. 2020; available on request). Eligible publications for this study were then reviewed to identify those that specifically reported on the pull-push project hazard–commodity combinations of *Campylobacter* and NTS in chicken meat, and ETEC and NTS in vegetables. This was done by screening titles and abstracts, assessing the full paper if the title and abstract were unclear.

3 Results

3.1 Search result

The broader all FBD hazards review returned 528 and 188 unique studies for Ethiopia and Burkina Faso, respectively. Titles and abstracts of these studies were screened, leading to the exclusion of 307 articles from Ethiopia and 148 articles from Burkina Faso. Full manuscripts of the remaining 221 articles from Ethiopia and 40 articles from Burkina Faso were accessed and downloaded; however, full papers for 14 articles in Ethiopia could not be accessed. Five studies identified from references of studies in Ethiopia were added, so the total number of full texts reviewed was 212 and 40 for Ethiopia and Burkina Faso respectively (Figure 1).

Figure 1. Flowchart of main search strategy and article selection for review of studies for all FBD hazards, then filtering only those reporting *Campylobacter* or NTS in chicken and those reporting NTS or ETEC in vegetables.



Screening of full articles left 142 articles for Ethiopia and 22 articles for Burkina Faso from which data were extracted. Finally, retaining only those addressing the four pull-push hazard–commodity combinations led to the exclusion of 133 articles for Ethiopia and 16 articles for Burkina Faso. One relevant study in Ethiopia was identified from related reading. Therefore, 10 articles for Ethiopia and 6 articles for Burkina Faso were selected and included in this report. A summary of these papers is presented in Table 1 below and Appendix B.

Table 1. Number of retained studies with suitable topic focus and quality

Country Food	Ethiopia				Burkina Faso			
	Vegetable		Chicken		Vegetable		Chicken	
Pathogen	<i>E. coli</i>	NTS	<i>Campylobacter</i>	NTS	<i>E. coli</i>	NTS	<i>Campylobacter</i>	NTS
No. papers	2	4	1	5	0	2	1	5

Pathogen paper count exceeds the total number of studies because three studies reported more than one relevant pathogen. *E. coli* reported due to absence of studies on ETEC.

3.2 Chickenvalue chain

Eleven papers reported *Campylobacter* and/or *Salmonella spp* in chicken meat (both countries). Of these, 10 studies described the prevalence of *Salmonella* in Ethiopia (n=5) and Burkina Faso (n=5). *Campylobacter* was reported in two studies, one from each country (Figure 2).

In both countries, studies mainly focused on *Salmonella* in the poultry value chain and used culturing and biochemical testing methods for isolation and identification of bacteria. Most of these studies, in addition to the prevalence reports, investigated antimicrobial susceptibility tests. Serotyping of *Salmonella* serotypes was also often reported. *Salmonella* concentration and counts were not reported.

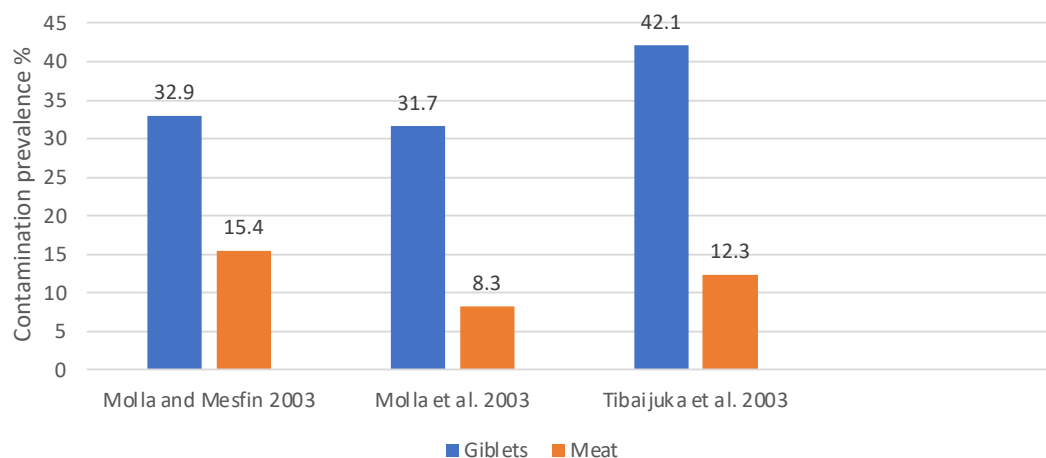
3.2.1 *Salmonella spp* in chicken value chain

3.2.1.1 *Salmonella spp* in chicken samples from Ethiopia

The five studies reporting *Salmonella spp* in chicken samples from Ethiopia. All of these studies were conducted in the central part of the country, mainly in the capital Addis Ababa and a town called Debre Zeit found 47 km southeast of Addis Ababa where the first veterinary school in Ethiopia and the National Veterinary Institute are found, and where there is a commercial chicken sector.

In Ethiopia surveys NTS in chicken meat and carcasses at prevalences of 8.3–15.4% in samples collected from markets in Addis Ababa and Debre Zeit (supermarkets, open markets, shops and processing plants) (Molla et al. 2003; Molla and Mesfin 2003; Tibaijuka et al. 2003; Zewdu and Cornelius 2009; Tadesse and Gebremedhin 2015).

Comparison of prevalence in different organs showed contamination of *Salmonella* was more common in the gizzard (41.1–53.1%) and liver (28–34.5%) compared to heart (21.2–23.7%) and meat (8.3–15.4%) (Molla et al. 2003; Molla and Mesfin 2003; Tibaijuka et al. 2003; Zewdu and Cornelius 2009). In three of the studies (Molla and Mesfin 2003, Molla et al. 2003; Tibaijuka et al. 2003) giblets (liver, heart and gizzard) had a higher contamination prevalence for of *Salmonella* than meat samples (Figure 2).

Figure 2. Comparison of *Salmonella* contamination in giblet and chicken meat samples collected from Ethiopia.

Salmonella contamination in chicken samples (23.6%, n=648) was higher compared to samples collected from beef (4.2%, n=1,856) and camel (16.2%, n=714) (Molla et al. 2003). Similar findings were reported by Zewdu and Cornelius (2009) where prevalence in chicken samples (13.9%, n=208) was higher compared to rates in pork (11.3%, n=194), mutton (10.8%, n=212), minced beef (8.5%, n=142), cottage cheese (2.1%, n=190) and fish (2.3%, n=128) samples. The pooled estimate of contaminated chicken meat (13.5%) was also higher compared to minced beef (8.34%), mutton (11.86%), pork (12.59%), and raw milk (10.76%) (Tadesse and Gebremedhin 2015).

3.2.1.2 *Salmonella* spp in chicken samples from Burkina Faso

In Burkina Faso Barro et al. (2002), Kagambèga et al. (2011, 2012, 2018) and Somda et al. (2018) reported contamination of chicken meat with *Salmonella*. These studies indicated that *Salmonella* contamination ranged from 37–90% in the dry season (Kagambèga et al. 2011, 2018) and 57% in the wet season (Kagambèga et al. 2012) in chicken carcasses collected from retail markets in Ouagadougou. However, *Salmonella* was absent in 102 cooked samples collected from food producers (66 grilled chickens, 29 flame-cooked chickens, 4 roasted chickens and 3 chickens prepared around the fire) (Somda et al. 2018). Interestingly, Kagambèga et al. (2018) indicated that eight chicken rinsing solutions collected from local chicken carcass sellers in four retail markets were all contaminated with *Salmonella*.

3.2.2 *Campylobacter* in chicken value chain

3.2.2.1 *Campylobacter* in chicken samples from Ethiopia

In a study conducted by Dadi and Asrat (2009), 60 chicken meat samples were collected from abattoirs (n=30) and supermarkets (n=30) in Addis Ababa and Debre Zehit. The overall prevalence of *Campylobacter* was 21.7% (n=13) and a higher prevalence (26.7%, n=8) was observed in abattoir samples than samples from supermarkets (16.7%, n=5). Like the findings in NTS, chicken meat was found to be more frequently contaminated than other raw meats (10.5% in mutton, 8.5% in pork, 7.6% in goat and 6.2% in beef).

3.2.2.2 *Campylobacter* in chicken samples from Burkina Faso

We identified one study (Kagambèga et al. 2018) in Burkina Faso that reported *Campylobacter* in chicken meat. In this study four chicken carcass-selling stalls at four large open markets located in low socio-economic status areas of Ouagadougou were visited. From the 20 carcasses collected and analysed, 10 were contaminated with *Campylobacter* (50%).

3.3 Vegetable value chain

From the current review on the impact of foodborne illnesses, *Salmonella* was reported in four studies from Ethiopia and two studies from Burkina Faso. Two of the studies from Ethiopia also reported *E. coli* contamination in vegetable samples.

3.3.1 ETEC in vegetables

None of the studies report ETEC specifically; however, two studies in Ethiopia reported *E. coli* in vegetables.

3.3.1.1 *E. coli* in vegetables samples from Ethiopia

Of the 21 vegetable salad samples collected from 21 juice houses (a type of restaurant) in Addis Ababa, 9 (52.4%) were positive for *E. coli* (Kechero et al. 2019). In Arba Minch (south Ethiopia), 100 tomato, 96 cabbage, 66 green pepper, 62 carrot and 23 lettuce samples collected from local markets were tested for *E. coli*. The contamination rate was 20%, 45.8%, 21.2%, 41.9% and 21.7% for the tomato, cabbage, green pepper, carrot and lettuce samples respectively. Cabbage was the most frequently contaminated vegetable in the present study. The authors attributed this to the fact that cabbage has a large surface area and coarse surface which enables contaminants to attach as compared to smooth-surfaced vegetables with a narrowly exposed outer surface like tomato. Among the bacterial species identified in this study, *E. coli* was the most commonly detected (31.4%) (Alemu et al. 2018).

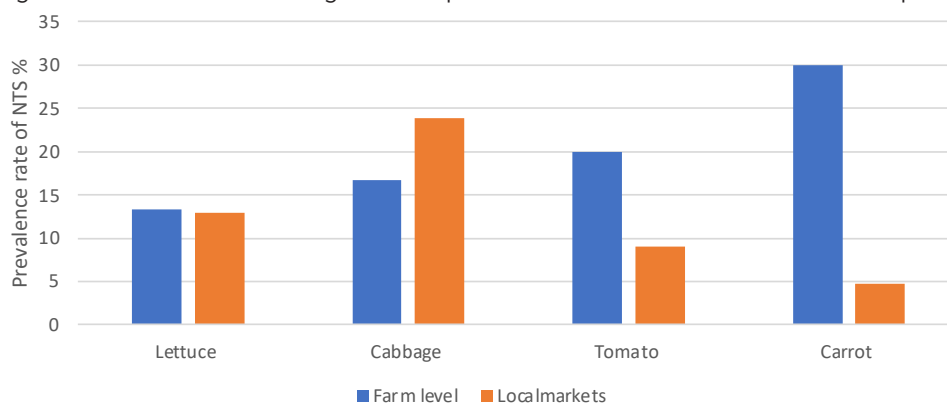
3.3.2 *Salmonella* in vegetable samples

Four studies were identified from Ethiopia that reported on *Salmonella* in vegetables (Guchi and Ashenafi 2011; Weldezigina and Muleta 2016; Alemu et al. 2018; Kechero et al. 2019) and two studies from Burkina Faso (Barro et al. 2002; Traoré et al. 2015).

3.3.2.1 NTS in vegetable samples from Ethiopia

Studies conducted in Addis Ababa indicated *Salmonella* contamination rates of 9.5% in 21 vegetable salad samples from juice houses (Kechero et al. 2019) and 10% in 40 lettuce and 40 green pepper samples purchased from different outlets (Guchi and Ashenafi 2011). The specific prevalence of *Salmonella* in lettuce and green pepper was not stated by Guchi and Ashenafi (2011). In samples collected from local markets in Arba Minch, *Salmonella* was found in tomato (9%, n=100), cabbage (23.9%, n=96), green pepper (12.1%, n=66), carrot (4.8%, n=62) and lettuce (13%, n=23) (Alemu et al. 2018). Weldezigina and Muleta (2016) determined the bacteriological load and safety of fresh vegetables irrigated with Awetu river water in Jimma town, southwestern Ethiopia. A total of 120 vegetable samples, 40 each from three sites with 10 samples each of lettuce, cabbage, tomato and carrot, were randomly collected. *Salmonella* contamination was observed in 13.3%, 16.7%, 20% and 30% of the lettuce, carrot, tomato and cabbage samples respectively. Seven (23.3%) of the 30 irrigation water samples collected from each site were positive for *Salmonella*. The authors suggested that the surface water pollution in this study may have originated from both human and animal sewage disposal by an informal settlement which lacks proper sanitation. Figure 3 below shows a comparison of NTS prevalence in samples collected at the farm level in Jimma town (Weldezigina and Muleta 2016) and from local markets in Arba Minch town (Alemu et al. 2018).

Figure 3. Prevalence of NTS in vegetable samples collected from farms and markets in Ethiopia.



Source: Farm level, Weldezigina and Muleta 2016; local markets, Alemu et al. 2018.

3.3.2.2 NTS in vegetable samples from Burkina Faso

Like the finding in Ethiopia, 10 (50%) of the 20 lettuce samples collected from vegetable farms in Ouagadougou were contaminated with *Salmonella* (Traoré et al. 2015). The authors suggested that the lettuce was contaminated by irrigation water, which comes from channels that are used as a human biological waste deposit by people living close to them, or manure used on adjacent fields. However, 32 salad samples collected from street food vendors in Ouagadougou were all negative for *Salmonella* (Barro et al. 2002).

3.4 Characterization of bacterial serotypes and species

Most of the studies in both countries conducted serotyping and characterization of bacteria species. Accordingly, in Ethiopia *Salmonella* serotypes commonly isolated from chicken meat samples were *S. Braenderup*, *S. Typhimurium* var Copenhagen and *S. Anatum* (Molla et al. 2003; Molla and Mesfin 2003; Tibajjuka et al. 2003; Zewdu and Cornelius 2009; Tadesse and Gebremedhin 2015). Table 2 below shows distribution of *Salmonella* serotypes in chicken meat and gible samples from Ethiopia.

Table 2. Number of positive samples reported for *Salmonella* serotypes in Ethiopian chicken meat and gible samples

Serotype	Author				Total
	Molla and Mesfin 2003	Molla et al. 2003	Tibajjuka et al. 2003	Zewdu and Cornelius 2009	
<i>S. Beraenderup</i>	35	52	17	12	116 (37%)
<i>S. Typhimurium</i> var Copenhagen	24	24	-	-	48 (15%)
<i>S. Anatum</i>	8	22	14	1	45 (14%)
<i>S. Kottbus</i>	5	5	-	-	10 (3%)
<i>S. Typhimurium</i>	3	18	2	3	26 (8%)
<i>S. Infantis</i>	2	2	-	-	4 (1%)
<i>S. Hadar</i>	2	2	-	6	10 (3%)

Serotype	Author				Total
	Molla and Mesfin 2003	Molla et al. 2003	Tibajjuka et al. 2003	Zewdu and Cornelius 2009	
<i>S. Bovismorbificans</i>	1	1	-	1	3 (1%)
<i>S. Saintpaul</i>	-	8	8	-	16 (5%)
<i>S. Uganda</i>	-	6	6	-	12 (4%)
<i>S. Enteritidis</i>	-	4	-	-	4 (1%)
<i>S. Haifa</i>	-	2	2	-	4 (1%)
<i>S. Virchow</i>	-	1	1	-	2 (1%)
<i>S. II 4: 12B</i>	-	2	-	-	2 (1%)
Rough form	-	2	2	-	4 (1%)
<i>S. Newport</i>	-	-	-	4	4 (1%)
<i>S. Kentucky</i>	-	-	-	2	2 (1%)
<i>S. Group B</i>	-	-	2	-	2 (1%)
Total	80	151	54	29	314

In Burkina Faso, *S. Derby* made up 47.3–50% of *Salmonella* serotype isolates identified from chicken carcass samples (Kagambèga et al. 2011, 2012). Moreover, of the 20 lettuce samples tested, 10 serotypes, predominantly *S. Colindale* (40%) and *S. Korlebu* (40%), were detected in Burkina Faso (Traoré et al. 2015). *Campylobacter jejuni* was characterized from 84.6% and 100% of positive chicken meat samples in Ethiopia and Burkina Faso respectively (Dadi and Asrat 2009; Kagambèga et al. 2018).

3.5 Antimicrobial susceptibility testing

Public health concerns about foodborne pathogens extend to antimicrobial resistance due to the continuing emergence, development and spread of pathogenic organisms that are resistant to antimicrobials (Kagambèga et al. 2011). Resistance of bacterial isolates to specific drugs could in part be due to the dissemination of drug resistance in the environment arising from the misuse of antibiotics (Guchi and Ashenafi 2011). In the present review, seven (43.75%) studies (Dadi and Asrat 2009; Zewdu and Cornelius 2009; Guchi and Ashenafi 2011; Kagambèga et al. 2011; Kagambèga et al. 2012; Weldezigina and Muleta 2016; Kechero et al. 2019) reported the isolation of antimicrobial-resistant isolates of *E. coli* and *Salmonella* in vegetables and *Campylobacter* and *Salmonella* in chicken meat.

Antimicrobial resistance of *Salmonella* from chicken carcass samples was reported in Ethiopia and Burkina Faso. Of these 29 *Salmonella* isolates from Ethiopia, 18 (62%) showed resistance patterns for up to 10 antimicrobials (Zewdu and Cornelius 2009). Even if the specific resistance patterns in chicken carcasses were not reported, the most dominant *Salmonella* serotype (*S. Derby*) was resistant to tetracycline, streptomycin and sulphonamide (Kagambèga et al. 2011). Similarly, *Salmonella* serotype (*S. Derby* and *S. Anatum*) isolates that were resistant to tetracycline and streptomycin were reported (Kagambèga et al. 2012). In the investigation conducted by Dadi and Asrat (2009), isolates from meat samples from Ethiopia showed lower resistance rates to most antimicrobial agents tested, with *C. jejuni* being resistant to streptomycin (20.5%), ampicillin (12.8%) and kanamycin (10.3%).

In vegetable value chains, resistant strains were investigated and observed in studies from Ethiopia. Accordingly, *E. coli* isolates (n=27) identified in fruit juices and vegetable salads were resistant to vancomycin (100%), penicillin (78%), sulphonamides (70%), ampicillin (67%), nitrofurantoin (63%) and amoxicillin (52%) (Kechero et al. 2019). *Salmonella* isolates were also reported to be resistant to a range of antibiotics, as shown in Table 3.

Table 3. Antibiotic resistance of isolated *Salmonella* species in vegetable value chains in Ethiopia

Commodity and publication	Antimicrobial resistance
Lettuce (Guchi and Ashenafi 2011)	Penicillin (100%) Amoxicillin (87.5%) Ampicillin (50%) Ceftriaxone (37.5%) Streptomycin (37.5%)
Water and vegetables (Weldezigina and Muleta 2016)	Cefuroxime sodium (100%) Penicillin (100%) Erythromycin (100%) Tetracycline (100%) Ampicillin (90.3%)
Fruit juices and vegetable salads (Kechero et al. 2019)	Penicillin (100%) Ampicillin (100%) Vancomycin (100%) Sulphonamides (67%) Ampicillin, trimethoprim and nitrofurantoin (each 33%)

4 Discussion

4.1 Chicken value chains

Salmonellosis and campylobacteriosis are among the most frequently reported FBDs worldwide (FAO/WHO 2009; Mir et al. 2015), with commercial chicken meat one of the most important food vehicles for these organisms (FAO/WHO 2009). Studies show that chicken are key asymptomatic carriers of *Campylobacter* and *Salmonella* spp, and the process of removing the gastro-intestinal tract during slaughtering can easily result in carcass and organ contamination with these pathogens (Mir et al. 2015).

The burden of bacterial FBD is disproportionately higher in African regions compared with other parts of the world, with the number of disability adjusted life years per 100,000 people exceeding that of other global regions (Havelaar et al. 2015). However, the sources and transmission routes of *Campylobacter* and *Salmonella* in developing countries are poorly understood due to the lack of coordinated national surveillance systems (Kariuki et al. 2006; Kagambèga et al. 2012).

In the present review, *Salmonella* prevalence in chicken carcasses was 8.3–15.4% in Ethiopia (Molla et al. 2003; Molla and Mesfin 2003; Tibaijuka et al. 2003; Zewdu and Cornelius 2009) and 37–90% in Burkina Faso (Kagambèga et al. 2011, 2012, 2018). *Salmonella* contamination reported at 90% in Ouagadougou, Burkina Faso (Kagambèga et al. 2018) was high when compared to other studies in Egypt (Moawad et al. 2017). This was not unexpected considering the unhygienic conditions and practices observed at the vending sites (Kagambèga et al. 2018).

In a recently conducted systematic review and meta-analysis on the prevalence of *Campylobacter* and *Salmonella* in African food animals and meat, contamination with *Salmonella* was 13.2% from 12,346 poultry meat and organ samples (Thomas et al. 2020). Higher *Salmonella* contamination rates have been reported from several studies outside Africa, e.g. 34% in Turkey (Yildirim et al. 2011), 66% in Thailand (Jerngklinchan et al. 1994) and 54% of retail poultry meat in Japan (Furukawa et al. 2017).

Repeated use of the same water for rinsing carcasses is commonplace in chicken slaughtering in Burkina Faso, and the importance of this for cross-contamination was emphasized by the 100% *Salmonella* contamination rates identified in water samples there (Kagambèga et al. 2018). Differences in prevalence of *Salmonella* in samples collected before rinsing (57%) (Kagambèga et al. 2012) and after rinsing (90%) further demonstrate this fact (Kagambèga et al. 2018).

In studies from Ethiopia, giblets (liver, heart and gizzard) had a higher contamination level of *Salmonella* than meat samples. Similar findings were observed from Egypt (Abd-Elghany et al. 2015). Cross-contamination of *Salmonella* from giblets to carcass could occur during handling, processing, packing, distribution and retail (Arumugaswamy et al. 1995; Uyttendaele et al. 1998). Rupture of the intestine could also occur during evisceration and pooling giblets might lead to cross-contamination of carcasses and other chicken parts. Molla and Mesfin (2003) observed that giblets were packed with the carcass in the processing plant and suggested this resulted in *Salmonella* cross-contamination.

Studies from both countries are highly concentrated in the capital cities (Addis Ababa and Ouagadougou). Barro et al (2002) suggested that in the case of Ouagadougou this may be due to a major part of the population having their breakfast, lunch and dinner in street food shops. Thus there is a high demand for animal sourced food, leading to the slaughtering of many animals with often poor infrastructure and hygiene.

Studies reported that *Salmonella* contamination in chicken meat was higher than in meat from other species (Molla et al. 2003; Zewdu and Cornelius 2009; Kagambèga et al. 2011; Tadesse and Gebremedhin 2015). Chicken meat could be a potential source of contamination for other foods, including other meats, with a greater risk during festive occasions where preparation of many varieties of meat dishes (raw, undercooked and cooked) is a common practice within households (Tadesse and Gebremedhin 2015). The high prevalence of *Salmonella* in chicken was explained to be due to asymptomatic carriage of *Salmonella* in avian caeca, which can lead to cross-contamination of the carcass during or after slaughter (Tibaijuka et al. 2003; Dione et al. 2011). The risk of contamination of meat by caecal contents is high in open markets in Burkina Faso and also Ethiopia where chickens are often slaughtered with poor hygiene (Kagambèga et al. 2011).

The two studies of *Campylobacter* reported prevalence of 50% in chicken meat samples in Burkina Faso and 21.7% in Ethiopia (Dadi and Asrat 2009; Kagambèga et al. 2018). Studies from rich and poor countries around the world report a range of prevalences, higher and lower.³

4.2 Vegetable value chains

The use of poor-quality irrigation water and raw animal manure for fertilizer is identified as a major source of contamination for fruits and vegetables with foodborne pathogens (Nutt et al. 2003). *Listeria monocytogenes*, *Salmonella spp* and *E. coli* have all been isolated from raw vegetables (Doyle 1990; Nguyen and Carlin 1994). Other literature also indicate identification of enteric pathogens from lettuce, tomato and cantaloupe, and outbreaks of salmonellosis have been reported due to consumption of contaminated tomatoes (Brandl 2006). Vegetables can be contaminated with enteric bacteria of public health importance during cultivation, harvest, transportation, processing and food preparation. The risk is particularly high in developing countries due to poor personal and environmental hygiene and weak public health systems (Okuy et al. 2004; Wegayehu et al. 2013).

In Ethiopia, *E. coli* was within a range of 20–52.4% in different vegetables samples (Alemu et al. 2018; Kechero et al. 2019). Contamination rates of vegetables by *Salmonella* ranged from 0% to 50% in Burkina Faso (Barro et al. 2002; Traoré et al. 2015) and 4.8% to 30% in Ethiopia (Guchi and Ashenafi 2011; Weldezigina and Muleta 2016; Alemu et al. 2018; Kechero et al. 2019). Similar prevalences are found in studies around the world.⁴

4.3 Identification of species and serotypes

Salmonella serotypes commonly isolated from chicken in Ethiopia and Burkina Faso were S. Braenderup and S. Derby (Molla et al. 2003; Molla and Mesfin 2003; Tibaijuka et al. 2003; Zewdu and Cornelius 2009; Kagambèga et al. 2011, 2012; Tadesse and Gebremedhin 2015). This finding has important implications because these serotypes are significant causes of food poisoning and enteric fever in humans (Osman et al. 2014).

³For example, *Campylobacter* was isolated from 71% of retail poultry meat in Japan (Furukawa et al. 2017). Studies in Africa showed prevalence in 81.9% of poultry meat in Nigerian processing plants and 100% in Nigerian retail outlets (Salihu et al. 2009; Olatoye and Ogunsemoyin 2016); between 11.1% and 100% in South African supermarkets (Ateba et al. 2014); 77% in raw chicken sourced from butcheries, markets and supermarkets in Kenya; and a prevalence close to 22% in Ghana (Karikari et al. 2017).

⁴*E. coli* was detected in 38.6% of fresh vegetable samples in Argentina (González et al. 2017) and in 16.7% of raw salad vegetable samples in India (Mritunjay and Kumar 2017). However, in a study in Canada *E. coli* was not detected in any of the fresh vegetables examined (Denis et al. 2016). In Nigeria, 40% of samples (spinach, carrot, cabbage, pumpkin leaf and water leaf) were contaminated by *Salmonella* (Omoigberale et al. 2014). The overall prevalence of *Salmonella* in raw vegetables was 3.4% in China (Yang et al. 2020) and 16% in Thailand (Phuket et al. 2019).

A worldwide epidemiological study of *Salmonella* serotypes in animal-based foods indicated that *S. Enteritidis* was the most prevalent in Asia, Latin America, Europe and Africa while *S. Kentucky*, *S. Typhimurium* and *S. Sofia* are the most prevalent serotypes in North America and Oceania (Ferrari et al. 2019).

Studies reviewed showed that *C. jejuni* was the predominant species in chicken meat samples in Ethiopia and Burkina Faso (Dadi and Asrat 2009 and Kagambèga et al. 2018). This finding was similar to reports from southern Benin (Kouglenou et al. 2020), Tunisia (Jribi et al. 2017), Italy (Di Giannatale et al. 2019), and Vietnam (Luu et al. 2006). *C. jejuni* is the most significant species responsible for foodborne enteritis in humans (Shane 1992). The *Salmonella* serotypes *S. Colindale* and *S. Korlebu* were also identified in lettuce in Burkina Faso (Traoré et al. 2015).

4.4 Antimicrobial resistance

Almost half of the relevant studies reported the isolation of antimicrobial-resistant serotypes of *E. coli* and *Salmonella* in vegetables and *Campylobacter* and *Salmonella* in chicken meat. Similarly, resistant strains of *Campylobacter* and *Salmonella* in chicken meat were reported elsewhere in Africa (Gaedirelwe and Sebunya 2008; Abdellah et al. 2009; Dione et al. 2011; Bester and Essack 2012; Hlashwayo et al. 2020).

Studies in the current review identified *E. coli* and *Salmonella* isolates in vegetables that were resistant to antimicrobials (Guchi and Ashenafi 2011; Weldezgina and Muleta 2016; Kechero et al. 2019). Similar findings are reporting for vegetables around the world (Faour-Klingbeil et al. 2016; Phuket et al. 2019; Yang et al. 2020). A significant proportion of these bacterial isolates have developed resistance to routinely prescribed antimicrobial drugs and pose considerable health hazards to the public unless prudent control measures are instituted (Nghiem et al. 2017).

4.5 Gaps in evidence

The importance of *Campylobacter* and *Salmonella spp* in chicken value chains and *Salmonella* and *E. coli* in vegetable value chains, especially in Africa where the disease burden from these pathogens is high compared with other parts of the world, has been reported in many studies. However, the evidence provided in this review of Ethiopia and Burkina Faso did not allow strong conclusions to be made. In part this was because only 16 (9.7%) studies were identified that focused on these specific hazards in chicken and vegetables. The only report of *Campylobacter* prevalence in Burkina Faso was conducted very recently (2018). Studies on ETEC in vegetable were absent and *Campylobacter* in chicken meat were scarce in both countries. This may be due to lack of sufficient resources for *Campylobacter* strain identification and detection of ETEC, which are complex (Kagambèga et al. 2021).

Regarding the sources of contamination the following are of note: cross-contamination of *Salmonella* between chicken carcasses from the use of the same carcass rinsing solution (Kagambèga et al. 2018); absence of *Salmonella* in one study of cooked chicken foods (Somda et al. 2018); and contamination of vegetables with *Salmonella* through irrigation water (Weldezgina and Muleta 2016). Other than these, sources of contamination were poorly explained.

Contamination with foodborne pathogens can occur at any point from farm to fork. More studies are required to identify pathways for contamination along chicken and vegetable value chains in order to target control measures for foodborne pathogens (Lamas et al. 2018). Furthermore, observation of many strains which are resistant to commonly used antimicrobials reflects the need to integrate antimicrobial resistance into food microbiological assessments.

5 Conclusion

Studies from Ethiopia on the prevalence of *Salmonella* in chicken meat indicate a high level of contamination and suggest that this is an important source of human salmonellosis; however, risk assessment considering quantities consumed should be done. The findings also underline the need for a coordinated surveillance and control program for salmonellosis and other major foodborne zoonotic diseases involving animals, food and people in Ethiopia. Studies from Burkina Faso highlight that poultry products on sale in Ouagadougou are widely contaminated with *Salmonella* and *Campylobacter*. This reflects a high food safety risk for consumers and highlights the need for improved awareness among consumers and those working in these value chains, and the need for food handlers to implement safe food handling practices. Vegetable contamination with *Salmonella* was also elevated in Burkina Faso, resulting from poor hygiene and contaminated irrigation water. Often improvements are required throughout the value chain to control FBD due to the many contamination routes from production to consumption.

Overall the literature was far from comprehensive, and evidence was absent, incomplete or fragmented, reflecting under-investigation, particularly for *Campylobacter* studies in chicken meat and ETEC in vegetables, with vegetables given less attention than chicken. Much remains to be done to provide a clear understanding of these hazards and their epidemiology in chicken and vegetable value chains in Ethiopia and Burkina Faso.

6 References

- Abd-Elghany, S.M., Sallam, K.I., Abd-Elkhalek, A. and Tamura, T. 2015. Occurrence, genetic characterization and antimicrobial resistance of *Salmonella* isolated from chicken meat and giblets. *Epidemiology of Infection* 143(5): 997–1003. <https://doi.org/10.1017/S0950268814001708>.
- Abdellah, C., Fouzia, R.F., Abdelkader, C., Rachida, S.B. and Mouloud, Z. 2009. Prevalence and anti-microbial susceptibility of *Salmonella* isolates from chicken carcasses and giblets in Meknès, Morocco. *African Journal of Microbiology Research* 3(5): 215–219.
- Alemu, G., Mama, M. and Siraj, M. 2018. Bacterial contamination of vegetables sold in Arba Minch Town, Southern Ethiopia. *BMC Research Notes* 11: 775. <https://doi.org/10.1186/s13104-018-3889-1>.
- Arumugaswamy, R.K., Rusul, G., Abdul Hamid, S.N. and Cheah, C.T. 1995. Prevalence of *Salmonella* in raw and cooked foods in Malaysia. *Food Microbiology* 12: 3–8. [https://doi.org/10.1016/S0740-0020\(95\)80072-7](https://doi.org/10.1016/S0740-0020(95)80072-7).
- Ateba, C., Mabote, K. and Mbewe, M. 2011. Prevalence of *Campylobacter* contamination in fresh chicken meat and milk obtained from markets in the North-West Province, South Africa. *Journal of Human Ecology* 36(1): 23–28. <https://doi.org/10.1080/09709274.2011.11906413>.
- Barro, N., Ouattara, C.A., Nikiema, P.A., Ouattara, A.S. and Traoré, A.S. 2002. Microbial quality assessment of some street food widely consumed in Ouagadougou, Burkina Faso. *Sante* 12 (4): 369–374.
- Bester, L.A. and Essack, S.Y. 2012. Observational study of the prevalence and antibiotic resistance of *Campylobacter* spp. from different poultry production systems in KwaZulu-Natal, South Africa. *Journal of Food Protection* 75(1): 154–159. <https://doi.org/10.4315/0362-028X.JFP-11-237>.
- Brandl, M.T. 2006. Fitness of human enteric pathogens on plants and implications for food safety. *Annual Review of Phytopathology* 44: 367–392. <https://doi.org/10.1146/annurev.phyto.44.070505.143359>.
- Dadi, L. and Asrat, D. 2009. Prevalence and antimicrobial susceptibility profiles of thermotolerant *Campylobacter* strains in retail raw meat products in Ethiopia. *Ethiopian Journal of Health Development* 22(2): 195–200. <https://doi.org/10.4314/ejhd.v22i2.10072>.
- Denis, N., Zhang, H., Leroux, A., Trudel, R. and Bietlot, H. 2016. Prevalence and trends of bacterial contamination in fresh fruits and vegetables sold at retail in Canada. *Food Control* 67: 225–234. <https://doi.org/10.1016/j.foodcont.2016.02.047>.
- Desalegn, W. 2021. Value chain analysis of vegetables (onion, tomato, potato) in Ethiopia: A review. *International Journal of Agricultural Science and Food Technology* 7(1): 108–113. <https://doi.org/10.17352/2455-815X.000096>.
- Di Giannatale, E., Calistri, P., Di Donato, G., Decastelli, L., Goffredo, E. et al. 2019. Thermotolerant *Campylobacter* spp. in chicken and bovine meat in Italy: Prevalence, level of contamination and molecular characterization of isolates. *PLOS One* 14(12): e0225957. <https://doi.org/10.1371/journal.pone.0225957>.
- Dione, M.M., Ikumapayi, U.N., Saha, D., Mohammed, N.I., Geerts, S. et al. 2011. Clonal differences between non-typhoidal *Salmonella* (NTS) recovered from children and animals living in close contact in the Gambia. *PLOS Neglected Tropical Diseases* 5(5): 1–7. <https://doi.org/10.1371/journal.pntd.0001148>.
- Doyle, M.P. 1990. Fruit and vegetable safety: Microbiological considerations. *Horticulture science* 25(12): 1478–1482.
- FAO/WHO (Food and Agriculture Organization/World Health Organization). 2009. *Salmonella and Campylobacter in chicken meat: Meeting report*. Microbiology Risk Assessment Series 19. Rome, Italy: FAO.

- Faour-Klingbeil, D., Kuri, V., Fadlallah, S. and Matar, G.M. 2016. Prevalence of antimicrobial-resistant *Escherichia coli* from raw vegetables in Lebanon. *The Journal of Infection in Developing Countries* 10(4): 354–362. <https://doi.org/10.3855/jidc.7745>.
- Ferrari, R.G., Rosario, D.K.A., Cunha-Neto, A., Mano, S.B., Figueiredo, E.E.S. and Conte-Junior, C.A. 2019. Worldwide epidemiology of *Salmonella* serovars in animal-based foods: A meta-analysis. *Applied and Environmental Microbiology* 85(14): e00591-19. <https://doi.org/10.1128/AEM.00591-19>.
- Furukawa, I., Ishihara, T., Teranishi, H., Saito, S., Yatsuyanagi, J. et al. 2017. Prevalence and characteristics of *Salmonella* and *Campylobacter* in retail poultry meat in Japan. *Japanese Journal of Infectious Diseases* 70(3): 239–247. <https://doi.org/10.7883/yoken.JJID.2016.164>.
- Gaedirelwe, O.G. and Sebunya, T.K. 2008. The prevalence and antibiotic susceptibility of *Salmonella* sp. in poultry and ostrich samples from slaughterhouses in Gaborone, Botswana. *Journal of Animal and Veterinary Advances* 7(9): 1151–1154.
- González, J., Cadona, J.S., Sanz, M., Bustamante, A.V. and Sanso, A.M. 2017. Molecular characterization of diarrheagenic *Escherichia coli* isolated from vegetables in Argentina. *International Journal of Food Microbiology* 261: 57–61. <https://doi.org/10.1016/j.ijfoodmicro.2017.09.021>.
- Grace, D., Alonso, S., Mutua, F., Roesel, K., Lindahl, J.F. and Amenu, K. 2018. *Food safety investment expert advice: Burkina Faso, Ethiopia, Nigeria*. Nairobi, Kenya: ILRI. <https://www.ilri.org/publications/food-safety-investment-expert-advice-burkina-faso-ethiopia-nigeria>
- Gross, B. and Jaubert, R. 2019. Vegetable gardening in Burkina Faso: Drip irrigation, agroecological farming and the diversity of smallholders. *Water Alternatives* 12(1): 45–67.
- Guchi, B. and Ashenafi, M. 2011. Microbial load, prevalence and antibiograms of *Salmonella* and *Shigella* in lettuce and green peppers. *Ethiopian Journal of Health Science* 20(1): 41–48. <https://doi.org/10.4314/ejhs.v20i1.69431>.
- Hailemariam, A. and Zemedu, L. 2018. Analysis of current status of poultry value chain in Ethiopia: Implication for information generation and exchange – A review. *Industrial Engineering Letters* 8(3): 100–111.
- Havelaar, A.H., Kirk, M.D., Torgerson, P.R., Gibb, H.J., Hald, T. et al. 2015. World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLoS Medicine* 12: e1001923. <https://doi.org/10.1371/journal.pmed.1001923>.
- Hlashwayo, D.F., Sigaúque, B. and Bila, C.G. 2020. Epidemiology and antimicrobial resistance of *Campylobacter* spp. in animals in sub-Saharan Africa: A systematic review. *Heliyon* 6(3): e03537. <https://doi.org/10.1016/j.heliyon.2020.e03537>.
- Jerngklinchan, J., Koowatananukul, C., Daengprom, K. and Saitanu, K. 1994. Occurrence of salmonellae in raw broilers and their products in Thailand. *Journal of Food Protection* 57(9): 808–810. <https://doi.org/10.4315/0362-028X-57.9.808>.
- Jribi, H., Sellami, H., Mariam, S., Smaoui, S., Ghorbel, A. et al. 2017. Isolation and identification of *Campylobacter* spp. from poultry and poultry by-products in Tunisia by conventional culture method and multiplex real-time PCR. *Journal of Food Protection* 80(10): 1623–1627. <https://doi.org/10.4315/0362-028X.JFP-16-321>.
- Kagambèga, A., Barro, N., Traoré, A.S., Siitonen, A. and Haukka, K. 2012. Characterization of *Salmonella enterica* and detection of the virulence genes specific to diarrheagenic *Escherichia coli* from poultry carcasses in Ouagadougou, Burkina Faso. *Foodborne Pathogen and Disease* 9(7): 589–593. <https://doi.org/10.1089/fpd.2011.1071>.
- Kagambèga, A., Haukka, K., Siitonen, A., Traoré, A.S. and Barro, N. 2011. Prevalence of *Salmonella enterica* and the hygienic indicator *Escherichia coli* in raw meat at markets in Ouagadougou, Burkina Faso. *Journal of Food Protection* 74: 1547–1551. <https://doi.org/10.4315/0362-028X.JFP-11-124>.
- Kagambèga, A., Thibodeau, A., Soro, D.K., Barro, N. and Fravallo, P. 2021. Detection of *Campylobacter* sp. from poultry feces in Ouagadougou, Burkina Faso. *Food and Nutrition Science* 12(2): 107–114. <https://doi.org/10.4236/fns.2021.122009>.
- Kagambèga, A., Thibodeau, A., Trinetta, V., Soro, D.K., Sama, F.N. et al. 2018. *Salmonella* spp. and *Campylobacter* spp. in poultry feces and carcasses in Ouagadougou, Burkina Faso. *Food Science and Nutrition* 6(6): 1601–1606. <https://doi.org/10.1002/fsn3.725>.
- Karikari, A.B., Obiri-Danso, K., Frimpong, E.H. and Krogfelt, K.A. 2017. Multidrug resistant *Campylobacter* in faecal and carcasses of commercially produced poultry. *African Journal of Microbiology Research* 11(7): 271–277.

- Kariuki, S., Revathi, G., Kariuki, N., Kiiru, J., Mwituria, J. et al. 2006. Invasive multidrug-resistant non-typhoidal *Salmonella* infections in Africa: Zoonotic or anthroponotic transmission? *Journal of Medical Microbiology* 55(5): 585–591. <https://doi.org/10.1099/jmm.0.46375-0>.
- Kechero, F.K., Baye, K., Tefera, A.T. and Tessema, T.S. 2019. Bacteriological quality of commonly consumed fruit juices and vegetable salads sold in some fruit juice houses in Addis Ababa, Ethiopia. *Journal of Food Safety* 39(1): e12563. <https://doi.org/10.1111/jfs.12563>.
- Kouglenou, S.D., Agbankpe, A.J., Dougnon, V., Djeuda, A.D., Deguenon, E. et al. 2020. Prevalence and susceptibility to antibiotics from *Campylobacter jejuni* and *Campylobacter coli* isolated from chicken meat in southern Benin, West Africa. *BMC Research Notes* 13: 305. <https://doi.org/10.1186/s13104-020-05150-x>.
- Lamas, A., Regal, P., Vázquez, B., Miranda, J.M., Cepeda, A. and Franco, C.M. 2018. *Salmonella* and *Campylobacter* biofilm formation: A comparative assessment from farm to fork. *Journal of Science, Food and Agriculture* 98(11): 4014–4031. <https://doi.org/10.1002/jsfa.8945>.
- Leight, J. and Martinez, E. 2020. *The impact of an integrated value chain intervention on household poultry production in Burkina Faso: Evidence from a randomized controlled trial*. IFPRI Discussion Paper 01919. Ouagadougou, Burkina Faso: IFPRI.
- Lina, M., Filipe, M., Pattama, U., Tadesse, G., Delia, G. et al. 2020. *Systematic literature review of foodborne disease hazards and burden in Ethiopia and Burkina Faso 1990–2019, with detailed 2017–19 update*. Unpublished report. Addis Ababa, Ethiopia: ILRI.
- Luu, Q.H., Tran, T.H., Phung, D.C. and Nguyen, T.B. 2006. Study on the prevalence of *Campylobacter* spp. from chicken meat in Hanoi, Vietnam. *Annals of the New York Academy of Sciences* 1081(1): 273–275. <https://doi.org/10.1196/annals.1373.036>.
- Mir, I.A., Kashyap, S.K. and Maherchandani, S. 2015. Isolation, serotype diversity and antibiogram of *Salmonella enterica* isolated from different species of poultry in India. *Asian Pacific Journal of Tropical Biomedicine* 5(7): 561–567. <https://doi.org/10.1016/j.apjtb.2015.03.010>.
- Moawad, A.A., Hotzel, H., Awad, O., Tomaso, H., Neubauer, H. et al. 2017. Occurrence of *Salmonella enterica* and *Escherichia coli* in raw chicken and beef meat in northern Egypt and dissemination of their antibiotic resistance markers. *Gut Pathogens* 9: 57. <https://doi.org/10.1186/s13099-017-0206-9>.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Altman, D. et al. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine* 6 (7): e1000097. <https://doi.org/10.1371/journal.pmed.1000097>.
- Molla, B., Alemayehu, D. and Salah, W. 2003. Sources and distribution of *Salmonella* serotypes isolated from food animals, slaughterhouse personnel and retail meat products in Ethiopia: 1997–2002. *Ethiopian Journal of Health Development* 17(1): 63–70. <https://doi.org/10.4314/ejhd.v17i1.9782>.
- Molla, B. and Mesfin, A. 2003. A survey of *Salmonella* contamination in chicken carcass and giblets in Central Ethiopia. *Revue de Médecine Vétérinaire (France)* 154(4): 267–270.
- Mritunjay, S.K. and Kumar, V. 2017. A study on prevalence of microbial contamination on the surface of raw salad vegetables. *3 Biotech* 7: 13. <https://doi.org/10.1007/s13205-016-0585-5>.
- Nghiem, M.N., Nguyen, V.T., Nguyen, T.T.H., Nguyen, D.T. and Vo, T.T.B. 2017. Antimicrobial resistance gene expression associated with multidrug resistant *Salmonella* spp. isolated from retail meat in Hanoi, Vietnam. *International Microbiology* 20(2): 85–93. <https://doi.org/10.2436/20.1501.01.288>.
- Nguyen, C. and Carlin, F. 1994. The microbiology of minimally processed fresh fruits and vegetables. *Critical Reviews in Food Science and Nutrition* 34(4): 371–401. <https://doi.org/10.1080/10408399409527668>.
- Nutt, J.D., Li, X., Woodward, C.L., Zabala-Díaz, I.B. and Ricke, S.C. 2003. Growth kinetics response of a *Salmonella typhimurium* poultry marker strain to fresh produce extracts. *Bioresource Technology* 89(3): 313–316. [https://doi.org/10.1016/S0960-8524\(03\)00084-1](https://doi.org/10.1016/S0960-8524(03)00084-1).
- Okay, P., Ertug, S., Gultekin, B., Onen, O. and Beser, E. 2004. Intestinal parasites prevalence and related factors in school children, a western city sample – Turkey. *BMC Public Health* 4: 64. <https://doi.org/10.1186/1471-2458-4-64>.
- Olatoye, O. and Ogunsemoyin, O. 2016. Prevalence and antibiotics resistance of *Campylobacter jejuni* in retail chickens in Oyo State, Nigeria. *Food Science and Quality Management* 46: 7–11.

- Omoigberale, M.N.O., Iyamu, M. and Amengialue, O.O. 2014. Bacteriological quality and prevalence of *Salmonella* in chicken product, fruits, and vegetables. *Global Journal of Biology, Agriculture and Health Sciences* 3(3): 252–255.
- Osman, K.M., Zolnikov, T.R., Samir, A. and Orabi, A. 2014. Prevalence, pathogenic capability, virulence genes, biofilm formation, and antibiotic resistance of *Listeria* in goat and sheep milk confirms need of hygienic milking conditions. *Pathogens and Global Health* 108(1): 21–29. <https://doi.org/10.1179/2047773213Y.0000000115>.
- Phuket, N.R. na, Surasak, S. and Wilailak, S. 2019. Prevalence of antibiotic-resistant *Salmonella* in vegetables and fermented foods and their control by lactic acid bacteria. *Journal of Pure and Applied Microbiology* 13(4): 1929–1939. <https://doi.org/10.22207/JPAM.13.4.05>.
- Rota, A. and Sperandini, S. 2010. *Gender and livestock: Tools for design*. In Brief. Rome, Italy: IFAD.
- Salihu, M.D., Junaidu, A.U., Magaji, A.A., Abubakar, M.B. and Adamu, A.Y. 2009. Prevalence of *Campylobacter* in poultry meat in Sokoto, Northwestern Nigeria. *Journal of Public Health and Epidemiology* 1: 41–45.
- Shane, S.M. 1992. The significance of *campylobacter jejuni* infection in poultry: A review. *Avian Pathology* 21(2): 189–213. <https://doi.org/10.1080/03079459208418836>.
- Somda, N.S., Bonkougou, O.J.I., Zongo, C., Kagambèga, A., Bassolé, I.H.N. et al. 2018. Safety of ready-to-eat chicken in Burkina Faso: Microbiological quality, antibiotic resistance, and virulence genes in *Escherichia coli* isolated from chicken samples of Ouagadougou. *Food Science and Nutrition* 6(4): 1077–1084. <https://doi.org/10.1002/fsn3.650>.
- Tadesse, G. and Gebremedhin, E.Z. 2015. Prevalence of *Salmonella* in raw animal products in Ethiopia: A meta-analysis. *BMC Research Notes* 8: 163. <https://doi.org/10.1186/s13104-015-1127-7>.
- Thomas, K.M., de Glanville, W.A., Barker, G.C., Benschop, J., Buza, J.J. et al. 2020. Prevalence of *Campylobacter* and *Salmonella* in African food animals and meat: A systematic review and meta-analysis. *International Journal of Food Microbiology* 315: 108382. <https://doi.org/10.1016/j.ijfoodmicro.2019.108382>.
- Tibaijuka, B., Molla, B., Hildebrandt, G. and Kleer, J. 2003. Occurrence of *salmonellae* in retail raw chicken products in Ethiopia. *Berliner und Münchener Tierärztliche Wochenschrift* 116 (1–2): 55–58.
- Traoré, O., Nyholm, O., Siitonen, A., Bonkougou, I.J.O., Traoré, A.S. et al. 2015. Prevalence and diversity of *Salmonella enterica* in water, fish and lettuce in Ouagadougou, Burkina Faso. *BMC Microbiology* 15: 151. <https://doi.org/10.1186/s12866-015-0484-7>.
- Uyttendaele, M.R., Debevere, J.M., Lips, R.M. and Neyts, K.D. 1998. Prevalence of *Salmonella* in poultry carcasses and their products in Belgium. *International Journal of Food Microbiology* 40(1–2): 1–8. [https://doi.org/10.1016/S0168-1605\(98\)00012-9](https://doi.org/10.1016/S0168-1605(98)00012-9).
- Wegayehu, T., Tsalla, T., Seifu, B. and Teklu, T. 2013. Prevalence of intestinal parasitic infections among highland and lowland dwellers in Gamo area, South Ethiopia. *BMC Public Health* 13: 151. <https://doi.org/10.1186/1471-2458-13-151>.
- Weldezigina, D. and Muleta, D. 2016. Bacteriological contaminants of some fresh vegetables irrigated with Awetu River in Jimma Town, Southwestern Ethiopia. *Advances in Biology* 2016: 1526764. <https://doi.org/10.1155/2016/1526764>.
- Yang, X., Wu, Q., Huang, J., Wu, S., Zhang, J. and Chen, L. 2020. Prevalence and characterization of *Salmonella* isolated from raw vegetables in China. *Food Control* 109: 106915. <https://doi.org/10.1016/j.foodcont.2019.106915>.
- Yildirim, Y., Gonulalan, Z., Pamuk, S. and Ertas, N. 2011. Incidence and antibiotic resistance of *Salmonella spp.* on raw chicken carcasses. *Food Research International* 44(3): 725–728. <https://doi.org/10.1016/j.foodres.2010.12.040>.
- Zewdu, E. and Cornelius, P. 2009. Antimicrobial resistance pattern of *Salmonella* serotypes isolated from food items and personnel in Addis Ababa, Ethiopia. *Tropical Animal Health and Production* 41: 241. <https://doi.org/10.1007/s11250-008-9181-y>.

Appendix A. Systematic literature review search terms used

Database	Country	Syntax
PubMed	Ethiopia	(foodborne OR 'food borne' OR food-borne OR 'food safety' OR 'food related' OR 'food associated' OR 'food derived' OR 'food* illness' OR 'food* disease*' OR 'food* intoxica*' OR 'food pathogen' OR 'food* poison*' OR 'food* microb*' OR 'food* vir*' OR 'food parasit*' OR 'food* toxin') AND (Ethiop*)
	Burkina Faso	(foodborne OR 'food borne' OR food-borne OR 'food safety' OR 'food related' OR 'food associated' OR 'food derived' OR 'food* illness' OR 'food* disease*' OR 'food* intoxica*' OR 'food pathogen' OR 'food* poison*' OR 'food* microb*' OR 'food* vir*' OR 'food parasit*' OR 'food* toxin') AND (Burkina*)
CAB Direct	Ethiopia	(title: (foodborne OR 'food safety' OR 'food borne' OR 'food related' OR 'food associated' OR 'food derived' OR 'food* illness' OR 'food* disease*' OR 'food* intoxica*' OR 'food pathogen' OR 'food* poison*' OR 'food* microb*' OR 'food* vir*' OR 'food parasit*' OR 'food* toxin') OR ab: (foodborne OR 'food safety' OR 'food borne' OR 'food related' OR 'food associated' OR 'food derived' OR 'food* illness' OR 'food* disease*' OR 'food* intoxica*' OR 'food pathogen' OR 'food* poison*' OR 'food* microb*' OR 'food* vir*' OR 'food parasit*' OR 'food* toxin')) AND (title: (Ethiop*) OR ab: (Ethiop*))yr:[2017 TO 2019]
	Burkina Faso	(title: (foodborne OR 'food safety' OR 'food borne' OR 'food related' OR 'food associated' OR 'food derived' OR 'food* illness' OR 'food* disease*' OR 'food* intoxica*' OR 'food pathogen' OR 'food* poison*' OR 'food* microb*' OR 'food* vir*' OR 'food parasit*' OR 'food* toxin') OR ab: (foodborne OR 'food safety' OR 'food borne' OR 'food related' OR 'food associated' OR 'food derived' OR 'food* illness' OR 'food* disease*' OR 'food* intoxica*' OR 'food pathogen' OR 'food* poison*' OR 'food* microb*' OR 'food* vir*' OR 'food parasit*' OR 'food* toxin')) AND (title: (Burkina*) OR ab: (Burkina*))yr:[2017 TO 2019]

Appendix B. Summary of studies from Ethiopia and Burkina Faso

Studies with specific hazard–commodity combinations in Ethiopia found in this SLR, 1990–2019

	Publication	Region	Hazard	No. of samples and prevalence
Vegetables	Guchi and Ashenafi 2011	Central Ethiopia (Addis Ababa)	<i>Salmonella</i>	80 samples from different outlets, 8 (10%) positive
	Kechero et al. 2019	Central Ethiopia (Addis Ababa)	<i>E. coli</i> and <i>Salmonella</i>	21 salad samples from vending houses, 11 (52.4%) positive for <i>E. coli</i> and 2 (9.5%) positive for <i>Salmonella</i>
	Alemu et al. 2018a	Southern Ethiopia (Arba Minch town)	<i>E. coli</i> and <i>Salmonella</i>	347 samples of cabbage, tomato, green pepper, carrot and lettuce from markets, 109 (31.4%) positive for <i>E. coli</i> and 46 (13.3%) positive for <i>Salmonella</i>
	Weldezgina and Muleta 2016	Southwestern Ethiopia (Jimma town)	<i>Salmonella</i>	120 samples of cabbage, tomato, carrot and lettuce from irrigated farms, 24 (20%) positive
Chicken	Molla et al. 2003	Central Ethiopia (Addis Ababa)	<i>Salmonella</i>	452 chicken meat samples from supermarkets, 54 (8.3%) positive
	Tadesse and Gebremedhin 2015	Meta-analysis on prevalence of <i>Salmonella</i> in raw animal products in Ethiopia	<i>Salmonella</i>	556 chicken meat samples from markets, pooled prevalence of 13.48%
	Tibaijuka et al. 2003	Central Ethiopia (Addis Ababa)	<i>Salmonella</i>	301 samples of chicken meat, gizzards and livers from supermarkets, 54 (17.9%) positive
	Zewdu and Cornelius 2009	Central Ethiopia (Addis Ababa)	<i>Salmonella</i>	208 chicken carcass samples from different markets, 29 (13.9%) positive
	Molla and Mesfin 2003	Central Ethiopia (Addis Ababa and Debre Zeit)	<i>Salmonella</i>	104 chicken meat samples from processing plants and markets, 16 (15.4%) positive
	Dadi and Asrat 2009	Central Ethiopia (Addis Ababa and Debre Zeit)	<i>Campylobacter</i>	60 chicken meat samples from abattoirs and supermarkets, 13 (21.7%) positive

Studies with specific hazard–commodity combinations in Burkina Faso found in this SLR, 1990–2019

	Publication	Region	Hazard	No. of samples and prevalence
Vegetables	Traoré et al. 2015	Ouagadougou	<i>Salmonella</i>	20 lettuce samples from irrigated farms, 10 (50%) positive
	Barro et al. 2002	Ouagadougou	<i>Salmonella</i>	32 salad samples from vendors, none positive
Chicken	Kagambèga et al. 2012	Ouagadougou	<i>Salmonella</i>	100 chicken carcass samples from retail markets, 57 (57%) positive
	Kagambèga et al. 2011	Ouagadougou	<i>Salmonella</i>	30 chicken meat samples from open markets, 11 (37%) positive
	Kagambèga et al. 2018	Ouagadougou	<i>Salmonella</i>	20 chicken carcass samples from retail markets, 18 (90%) positive
		Ouagadougou	<i>Campylobacter</i>	20 chicken carcass samples from retail markets, 10 (50%) positive
	Barro et al. 2002	Ouagadougou	<i>Salmonella</i>	28 fresh chickens found to have 2.11(6) CFU/g of <i>Salmonella</i> and <i>Shigella</i> , while these microbes were absent in 32 grilled chicken samples
	Somda et al. 2018	Ouagadougou	<i>Salmonella</i>	102 chicken samples from producers, none positive

92-9146-689-0



The International Livestock Research Institute (ILRI) works to improve food and nutritional security and reduce poverty in developing countries through research for efficient, safe and sustainable use of livestock. Co-hosted by Kenya and Ethiopia, it has regional or country offices and projects in East, South and Southeast Asia as well as Central, East, Southern and West Africa. ilri.org



CGIAR is a global agricultural research partnership for a food-secure future. Its research is carried out by 15 research centres in collaboration with hundreds of partner organizations. cgiar.org