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The U.S. Government's Global Hunger & Food Security Initiative

EatSafe: Evidence and Action Towards Safe, Nutritious Food

Literature Review on Foodborne Disease Hazards in Food and Beverages in Ethiopia

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This EatSafe report presents evidence that will help engage and empower consumers and market actors to better obtain safe nutritious food. It will be used to design and test consumer-centered food safety interventions in informal markets through the EatSafe program.

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ACRONYMS AND ABBREVIATIONS

CFU	Colony Forming Unit
DALYs	Disability Adjusted Life Years
EatSafe	Evidence and Action Towards Safe, Nutritious Food
FAO	Food and Agriculture Organization of the United Nations
FBD	Foodborne diseases
FERG	Foodborne Disease Burden Epidemiology Reference Group
GAIN	Global Alliance for Improved Nutrition
HICs	Higher-Income-Countries
ILRI	International Livestock Research Institute
LMICs	Lower- and Middle-Income Countries
Log 10	Logarithm base 10
USAID	Agency for International Development
WHO	World Health Organization

EXECUTIVE SUMMARY

Ethiopia bears a significant burden of foodborne disease (FBD). As in other African countries, traditional markets play a vital role in suppling food to Ethiopian consumers. However, little if any oversight exists to monitor the safety of foods sold at those markets. Conditions at the market itself could contribute to food contamination, for example due to inadequate infrastructure, vending practices, or poor environmental health. Feed the Future's EatSafe: Evidence and Action Towards Safe, Nutritious Food (EatSafe) undertook a comprehensive two-part review of the published literature to synthesize existing evidence on the occurrence of biological and chemical hazards in foods and beverages in Ethiopia.

This report is organized in three parts: Section 1 presents objectives and methodology, while Sections 2 and 3 present findings on hazard occurrence in food and beverages, respectively. Section 2 details findings from recent literature review efforts, synthesizing 97 articles published from 1990 to 2021 on chemical and biological hazards detected in foods sold and consumed in Ethiopia. Section 3 presents methods and findings of a new literature review conducted by EatSafe on beverage-borne hazards consumed in Ethiopia, covering 118 articles published from 2000 to 2021.

Regarding hazard occurrence in foods (**Section 2**), 70% of included studies investigated the presence of bacterial hazards. In animal source foods, in particular the beef and dairy value chains, *Salmonella* spp., *E. coli,* and *Staphylococcus aureus* were documented most frequently. This level of attention seems justified by the high contamination prevalence observed, although there may be a bias likely due to the importance of these commodities in the Ethiopian food economy. Conversely, data are lacking on viral pathogens and parasites. While some studies found fresh vegetables to be highly contaminated with parasites and bacteria, comparatively little data was available for this commodity category, thus supporting the choice of fresh vegetables as a focus for EatSafe's activities. Only three studies reported on egg contamination.

Regarding hazard occurrence in beverages (**Section 3**), 58% of included studies covered raw or pasteurized cow milk and camel milk. A quarter of records (28%) covered water, while 13% examined fruit juices. More biological hazards (n=469) than chemical hazards (n=70) were identified. Almost all (94%) biological hazards were bacteria, while a small portion were fungi and parasites (5% and 1%, respectively). Of the bacterial hazards, the most frequently reported were *Escherichia coli* (21%), *Staphylococcus* spp. (22%), and *Salmonella* spp. (11%). Antimicrobial residues, heavy metals, and pesticides were also reported by a small number of studies.

In general, results from the reviews were compatible with disease burden estimates from the World Health Organization's Foodborne Disease Epidemiology Reference Group (FERG), the most credible global source of FBD burden estimates. Notably, *Salmonella* spp. and *E. coli* feature prominently in both the reviews and FERG estimates. However, certain hazards that the FERG considers high priority but are difficult to assess (e.g., *Campylobacter* spp.) are underreported in the reviews. Moreover, while the FERG did not consider *S. aureus*, this was one of the most reported bacteria in the reviews.

This report represents an important step in gathering and synthesizing scientific evidence to inform upcoming EatSafe research activities and interventions to improve food safety in traditional markets in Ethiopia.

I. INTRODUCTION

Although access to safe food is a basic human right (1), foodborne diseases (FBD) continue to present significant global health challenges. FBD is caused by food that carries bacteria, viruses, parasites, foreign material, and chemicals that makes food unsafe for human consumption.

The Foodborne Disease Burden Epidemiology Reference Group (FERG), a World Health Organization (WHO) group of experts focused on FBD, provides the best estimates of the foodborne disease burden globally (2,3). Using global data on 31 foodborne hazards, the FERG estimates about 600 million people become sick each year and 420,000 die, resulting in an estimated FBD burden of 33 million Disability Adjusted Life Years (DALYs)(4).[1] A subsequent FERG study estimated a burden of over one million additional disease cases, 56,000 deaths, and nine million DALYs attributed to four foodborne heavy metals (i.e., arsenic, cadmium, lead, and methylmercury) (5). Additional detail on bacterial, viral, and chemical disease agents from the FERG studies are in **Table 1**.

Table 1. *Hazards associated with the highest global FBD burden per year, within each category (2)*

HAZARD	DALYs	CASES (#)	DEATHS (#)	DALYs/100,000 PEOPLE IN SUBREGION AFR E
BACTERIAL AND VIRAL				
Non-typhoidal *Salmonella enterica*	4,067,929	78,707,591	59,153	193 (44-336)
Vibrio cholera	1,722,312	763,451	24,649	143 (4-343)
Enteropathogenic *E. coli*	2,938,407	23,797,284	37,077	138 (6-327)
Enterotoxigenic *E. coli*	2,084,229	86,502,735	26,170	105 (17-240)
Norovirus	2,496,078	124,803,946	34,929	76 (0-225)
Campylobacter spp.	2,141,926	95,613,970	21,374	70 (33-117)
Shigella	1,237,103	51,014,050	15,156	37 (0-148)
Shiga-toxigenic *E. coli*	12,953	1,176,854	128	0.08 (0.02-0.2)
CHEMICAL				
Lead	5,243,184	583,569	0	82 (0-707)
Methylmercury	1,963,869	226,655	0	37 (9-210)
Arsenic	1,338,879	199,422	49,451	13 (3-24)
Aflatoxin	636,869	21,757	19,455	3 (1-8)
Cassava cyanide	8,203	1,066	227	3 (0.3-9)
Cadmium	70,513	12,224	2,064	1 (0.1-12)
Dioxins	240,056	193,447	0	0.2 (0.09-9)

[1] One DALY is equivalent to one year of "healthy" life that is lost.

Regionally, the FERG found that for two of the four heavy metals listed above, Africa sub-region E[2] had the top two highest FBD burden per capita. Ethiopia, the focus of this report, belongs to that sub-region. As shown in **Table 1**, the top five hazards as per DALY burden are biological. While non-typhoidal *Salmonella* ranks highest in terms of DALYs and deaths, *Campylobacter* spp. and norovirus rank first and second in illness numbers – reflecting frequent but less severe illnesses.

1.1. OBJECTIVES AND STRUCTURE OF THIS REPORT

Feed the Future's Evidence and Action Towards Safe, Nutritious Food (EatSafe) aims to improve food safety in traditional food markets by focusing on the consumer. This report presents the existing body of evidence on the occurrence of foodborne hazards in foods and beverages commonly consumed in Ethiopia. In conjunction with other research studies, this report will inform the design of EatSafe's consumer-facing interventions in Ethiopia.[3]

This report is organized in two parts:

- Section 2 on Hazards in Foods, which synthesizes results from a review of foodborne hazards in Ethiopia from 1990 to 2021 (3);
- Section 3 on Hazards in Beverages, which presents the results of a new review of beverage-borne hazards in Ethiopia from 2000 to 2021.

The following research questions grounded both reviews:

- What biological and chemical hazards have been identified in foods and beverages consumed in Ethiopia?
- What is the prevalence (i.e., percent of contaminated products) and concentration of hazards in foods and beverages consumed in Ethiopia?
- What is the spatial distribution of studies reporting these hazards (i.e., where, within the country, were the studies conducted)?

2. FOODBORNE HAZARDS REVIEW

2.1. METHODOLOGY

EatSafe consortium partner ILRI previously conducted a systematic literature review covering a broad range of foodborne hazards in Ethiopia, including evidence from 1990-

[2] Countries in this sub-region include: Botswana; Burundi; Central African Republic; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Eritrea; *Ethiopia*; Kenya; Lesotho; Malawi; Mozambique; Namibia; Rwanda; South Africa; Swaziland; Uganda; United Republic of Tanzania; Zambia; Zimbabwe. Note these countries are classified in the same sub-region based on similar levels of mortality, as Africa sub-region E corresponds to high child and very high adult mortality.

[3] In particular, this review will inform the choice of specific hazard(s) and commodities that will be included in EatSafe risk assessment activities in Ethiopia.

2017 (3). A second supplemental review was conducted to identify more recently published articles, covering 2017-2021. This section summarizes findings from both searches. The search protocol for the systematic review is detailed in (3), and the supplemental search used the same methods. Data was extracted from 97 articles that fulfilled the inclusion criteria and met acceptable quality standards.

2.2. FINDINGS

Of the 97 articles selected for data extraction, the vast majority (70%) investigated the presence of bacterial hazards (**Figure 1**), followed by 20% on parasites. Only a minority of articles addressed viruses or chemical hazards. The distribution of bacterial hazards, in terms of percent of articles, is shown in **Figure 2**.

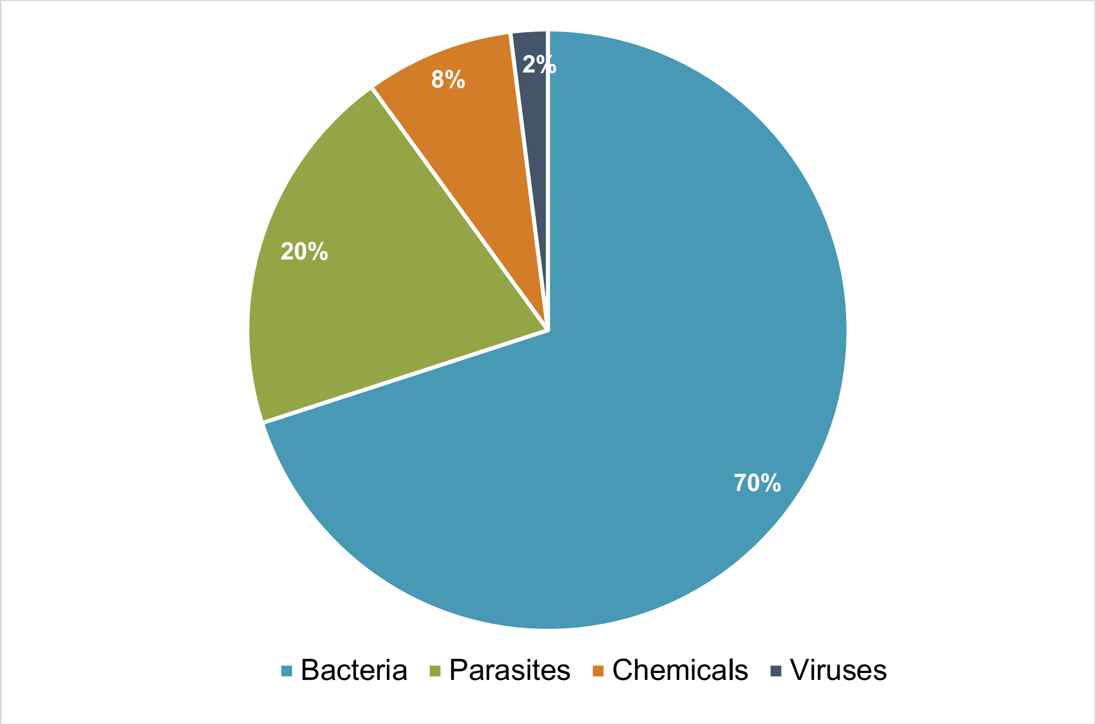

Figure 1. *Foodborne hazard categories identified in the review (% of articles)*

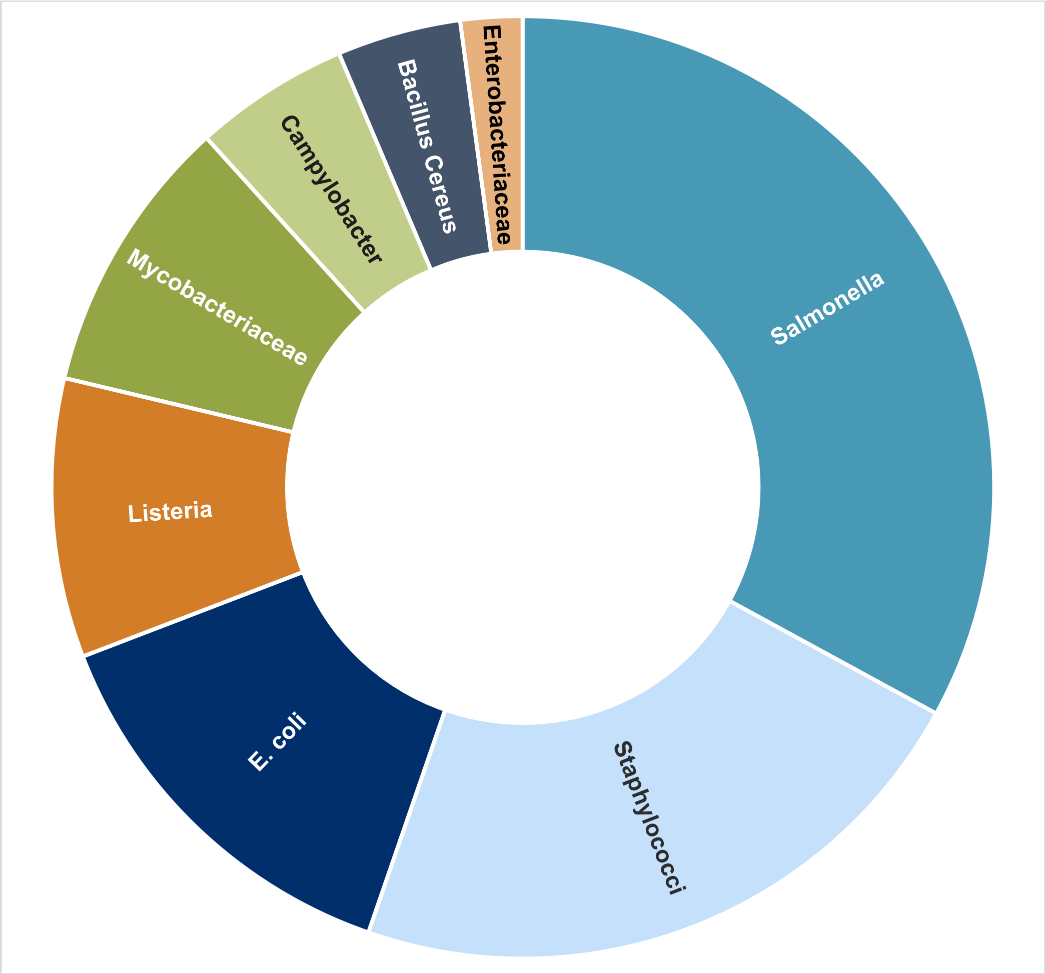

***Figure 2**. Illustrative distribution of bacterial hazards studied in foods in Ethiopia*

In terms of value chains, bovine dairy and beef were the most studied. The focus on these two value chains is possibly a reflection of the importance of livestock in Ethiopian food systems, and of funding to support research on them.

More recent results from the supplemental search confirm these hazard prevalence rates. While gaps in several hazards and commodities remain, EatSafe identified an increase in published literature for vegetables from 2017 to 2021.

The most investigated and detected hazards are pathogenic bacteria (**Figure 2**). While each species or subspecies results in different clinical presentations, most can cause acute gastroenteric illness, often including diarrhoea and associated complications, as well as numerous long-term sequelae of infection. Several of these pathogens are estimated to cause the highest burden among FBD, worldwide and in the Africa subregion AFR-E including Ethiopia (2). Among chemical hazards, long-term exposure to aflatoxins can lead to carcinogenicity, in particular liver cancer, immunotoxicity, and growth impairment, as well as acute liver toxicity in extreme cases (6).

The following sections presents results by value chain.

2.2.1. BOVINE DAIRY PRODUCTS

Six articles investigating microbial contamination in the bovine dairy products value chain (excluding milk and yogurt, covered in the beverage review) were identified, covering four bacterial pathogens and one suspect pathogen (*Mycobacterium*). Five hazards were identified in various stages of the Ethiopian bovine dairy value chain: *Staphylococcus, Listeria, Bacillus cereus, Salmonella,* and *Mycobacterium.*[4]

***Staphylococcus* spp. –** This pathogen enters the dairy production chain when it is shed in milk by cows. The likelihood that cows shed *S. aureus* varies based on geographical location and farming systems but is closely related to hygiene practices during milk handling. While five studies investigated the occurrence of *S. aureus* in bovine milk, and found a prevalence ranging from 7% to 50% at multiple stage of the milk production and processing chain (7–10); see Section 3), no study investigated the presence of this pathogen in cheese or other dairy foods.

***Listeria* spp. –** Studies in Addis Ababa identified *Listeria* spp. in ice cream (43% of samples), cheese (0%-4%), and cottage cheese (2%-5%) (11–14). In a different study, cheese was found to be highly contaminated with the hazard (60%), more so than raw milk (19%) and yogurt (5%) (15). While pasteurization will kill this bacterium, 20% of pasteurized milk samples still contained this pathogen, likely due to cross-contamination during processing (15).

***Bacillus cereus* –** Over 60% of ayib samples (an Ethiopian traditional cheese) sold at a traditional market were contaminated with *Bacillus cereus* (11).

***Salmonella* spp. –** In supermarkets and retail shops located in Gondar, *Salmonella* spp. was not detected in cottage cheese samples (16). For context, over 10% of individuals working in Addis Ababa dairy farms were found positive for *Salmonella* (10).

***Mycobacterium* spp. –** No study investigated the presence of this genus in bovine dairy products other than milk. A large study involving cattle (n=1,220) found *Mycobacterium tuberculosis* (15%), *M. bovis* (44%) and atypical mycobacteria (39%) in

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[4] *Mycobacterium* spp. is of primary importance for animal health and only a suspect human pathogen. Because the foodborne hazard review excludes milk, it is mentioned here for completeness. However, the three articles described in the *Mycobacterium* sub-section are excluded from the number of studies in the foodborne hazard review, instead included in the beverage review (Section 3).

milk from tuberculin-positive cows (17). Two other studies found that 8%-18% of tuberculin sensitive cows were shedding *M. bovis* or *M. tuberculosis* in milk (11%) (18,19).[5]

2.2.2. BEEF

Because consumption of raw beef meat is common in Ethiopia, the presence of foodborne pathogens is particularly relevant to this value chain. A total of 23 studies investigated microbial contamination in the beef value chain.

***Salmonella* spp. –** *Salmonella* was detected in 12% of raw meat samples, 8% of minced meat samples, and 3% of raw burger samples (16). In another study, only two of 200 (1%) beef samples were positive for *Salmonella* spp. (20). *Salmonella* was observed in raw beef products at a prevalence ranging from 2% to 26% in abattoirs, and 4% to 70% in retail (21–26).

***Listeria* spp. –** Approximately half of 61 minced beef meat samples analyzed in one study (14) were positive for *Listeria* spp., and one of these positive samples was confirmed as *L. monocytogenes* (14). Another study found a 28% prevalence of *Listeria* spp. Four percent of beef samples contained *L. monocytogenes,* which has higher rates of antimicrobial resistance (27).

***E. coli* O157 –** Eight studies examined the prevalence of *E. coli* in beef samples. One study found a *E. coli* O157 prevalence of 8% in meat samples from abattoirs and butcher shops in Addis Ababa (28). Six recent articles investigated the presence of generic *E. coli* in raw beef meat or carcasses in the Oromia region. Prevalence in raw beef meat products sampled at abattoirs or retail ranged from 19% to 45%, with the highest prevalence observed at retail (22,29,30). In particular, prevalence of *E.coli* O157:H7 ranged from 1% to 19% at abattoirs and retail. (29–32). One study focusing *E.coli* O157:H7 on carcass swabs at processing plants (including skin, intestinal, and fecal swabs) found a much lower prevalence of 1-2%, possibly due to the sampling method used, or to the processing plant exhibiting a higher degree of food safety controls than other establishments (33).

***Shigella* spp. –** A study involving butcher shops in Gondar town isolated *Shigella* in 9% of raw meat samples. Contamination was also reported in swabs of chopping boards (13%), hands (11%), and knives (11%) (34).

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[5] Shedding refers to the transfer of microbes from one living animal to another (Note this can include humans). The route of shedding may include milk, feces, coughing, or milk.

***Staphylococcus aureus* –** *S. aureus* was identified in 12% to 25% of raw beef products in abattoirs (7,22) and in half of butcher shop beef samples (35). In another study on environmental samples in abattoirs, four knife and slaughter line swab samples tested positive for S. aureus, as did all hand swabs (7). Assessing concentrations in raw beef samples collected at urban butcher shops, one study found a mean of 4 Log CFU/g, considered unacceptably high (21).

***Mycobacterium bovis* –** In one study, 6% of carcasses were found positive for *M. bovis* upon postmortem examination (36). The study also found poor agreement between routine and detailed abattoir inspection, and well as between results of inspection and culture detection, with 14% of carcasses harboring mycobacteria that were not detected by the detailed abattoir inspection. While *Mycobacterium* spp. is of primary importance for animal health, it is a suspect human pathogen and included here for completeness.

2.2.3. EGGS

Four studies on eggs were identified. A study in Addis Ababa found that 5% of raw shell egg samples were positive for *Salmonella enteritidis* (n=384) (37). In another study, 18% (n=50) of raw egg samples were found positive for *Salmonella* spp. (16). Finally, *Salmonella* was also detected in one out of 30 egg sandwich samples (38). One study found a somewhat higher prevalence of *Salmonella* in eggs sold at markets (4-5%) than in eggs collected at farms (0-2%) (39).

2.2.4. FRUITS AND VEGETABLES

A total of six studies on fresh vegetables were identified (see **Table 2**). Most studies focused on parasites – unlike for other commodities – and only one study investigated bacteria. No study examined viral occurrence, highlighting a key gap in evidence on foodborne hazards and risk.

Parasites – Four studies investigated the presence of parasites in fruits and vegetables. One study found that half of the 36 fruit and vegetable sampled tested positive for at least one parasite, and of those testing positive, half were contaminated with two parasite species (40).[6] Contamination rates differed by product type, and included 71% of tomatoes, 67% of kale (*Brassica oleracea*), 62% of carrots, 60% of lettuce (*Lactuca serriola*), 49% of bananas, 40% of mangoes, and 38% of avocado samples. Two other small-scale studies confirmed the prevalence levels observed for individual parasites. However, one large recent study found a relatively lower

[6] *A. lumbricoides* (21%) was the most frequently detected parasite, followed by *Toxocara* spp. (16%), *Hymenolepis nana* (16%), *Entamoeba histolytica* or *E. dispar* (14%), and *Giardia intestinalis* (10%).

prevalence of some parasites in multiple vegetable sampled at markets in Bahir Dar City (41).

Bacterial contamination – Varying levels of microbial contamination were identified in fruits and vegetables. In one study of lettuce and green peppers (each n=40), *Salmonella* was detected in 10% of samples and *Shigella* in 30% (100% and 97% penicillin-resistant, respectively), in addition to coliform counts above 4 Log CFU/g in 48% and 35% of lettuce and green pepper samples, respectively (42). In the same study, 80% of samples had high *Staphylococcus* counts (between 4 and 6 Log CFU/g). A different study examined the presence of *E. coli* O157:H7 in lettuce sold at Addis Ababa markets found a relatively low (0.5%) prevalence (43).

Table 2. *Detection of microbial hazards in fresh fruits and vegetables in Ethiopia*

COMMODITY, REF.	HAZARD/TARGET	CONTAMINATION LEVEL
Multiple FFV: avocado, lettuce, cabbage, carrot, tomato, banana, mango (40)	Parasites	54% any parasite (n=36) *A. lumbricoides* (21%), *Toxocara* spp. (16%), *Hymenolepis nana* (16%), *E. histolytica/E. dispar* (14%), *Giardia intestinalis* (10%), *H. diminuta* (8%), *Cyclospora* spp (7%), *Cryptosporidium* spp (5%), *Cystoisospora belli* (3%)
Lettuce, green peppers (42)	Coliforms, fungi, bacteria	n=40 for commodity *Salmonella*: 10% (lettuce and peppers), *Shigella*: 12.5% (lettuce), 25% (peppers) *Staphylococci* mean levels: 4.6 Log CFU/g (lettuce), 5 Log CFU/g (peppers)
Multiple fresh vegetables: tomato, lettuce, carrot, cabbage, green peppers (40)	Parasites	n=45 *A. lumbricoides* (7% - 27%), *Toxocara* (4% - 24%), *Hymenolepis nana* (0% - 18%), *E. histolytica/E. dispar* (2% - 16%), *Giardia intestinalis* (2% -18%), *H. diminuta* (0% - 16%), *Cystoisospora belli* (0% - 9%)
Multiple fresh vegetables: pepper, lettuce, cabbage. guava (44)	Parasites	*Cryptosporidium* spp.: 0-17% (Pepper 11%, n=9; Lettuce 0%, n=13; Cabbage 8%, n=12; Guava 17%, n=6) *Giardia lamblia*: 0-17% (Pepper 0%, n=9; Lettuce 15%, n=13; Cabbage 17%, n=12; Guava 17%, n=6)

Multiple fresh vegetables: cabbage, spinach, lettuce, carrots (41)	Parasites	n=384 *Cryptosporidium* spp.: 1% - 2% *E. histolytica*/*E. dispar*: 2% - 4% *Giardia lamblia*: 1% - 3% *Strongyloides* spp.: 1% - 4%
Lettuce (43)	*E. coli* O157:H7	n=390, 0.5%

2.2.5. GRAINS, NUTS, AND SEEDS

Four articles reporting on chemical hazards in grains, nuts, and seeds were identified.

In one study examining mycotoxins, ochratoxin was the most frequently identified hazard, isolated in teff (27%; n=33), wheat (23%; n=107), sorghum (22%; n=78) and barley (26%; n=103) (45). Aflatoxin B1 was found in teff (23%; n=35) and barley (11%; n=115), while deoxynivalenol was identified in 90% of sorghum (n=33) and 35% of barley (n=20) samples (45).

Aflatoxin prevalence ranged from 23% to 41% in samples of groundnut seeds and locally produced groundnut cake (halawa) over two consecutive crop seasons (n=80 in each year) [7] (46). Beyond groundnut products, another study of mycotoxin contamination in maize from farms in south and southwest Ethiopia found high concentrations[8] of Zearalenone compounds, Fumonisins B1-B4, and Aflatoxin B1(47).

In another study, all samples of maize consumed were contaminated with Dichlorodiphenyltrichloroethane (DDT), at a mean concentration of 1.8 mg/kg (48). Specifically, over three-quarters of maize samples for human consumption collected from households at three sites contained levels above the standards set by the European Union and/or the Codex Alimentarius (i.e., maximum residue levels for DDT/DDE in maize 0.05 and 0.1 mg Kg^{-1} respectively) (49,50), highlighting the potential risk when maize is used as an ingredient in complementary foods. This study also investigated organochlorine and organophosphate pesticide residues in other cereal crops (sorghum, millet, rice).

[7] Concentration levels in both products combined ranged from 1.7 to 2,526 µg kg^{-1} for B1, and from 0.1 to 237 µg kg^{-1} for B2.

[8] Prevalence of Aflatoxin B1 was 8% (mean concentration of 606 µg kg^{-1}), 51% to 70% for Fumonisins B1-B4 (mean concentrations of 85-606 µg kg^{-1}), and 81% to 96% for Zearalenone compounds.

2.3. COMPARISON OF FINDINGS TO FERG ESTIMATES

The findings on contamination levels of the review, presented in the previous section, was consistent with estimates of disease attribution to different commodity categories in the FERG estimates, for the Africa sub-region E including Ethiopia (4). In particular non-typhoidal *Salmonella*, one of the most important bacteria in terms of public health, was studied in numerous publications in Ethiopia (and elsewhere). However, viruses were under-represented and chemicals over-represented in the publications identified by the review, compared to FDB burden attributed to them in the FERG estimates. This highlights that viruses are relatively understudied compared to their estimated burden. The high representation of chemical hazards in the published literature is possibly an indication of increased funding for research targeting them. The review also searched for and identified publications on important foodborne pathogens that were not included in the FERG study (e.g., *Staph. aureus* and *Bacillus cereus*). It should be kept in mind that hazard occurrence data cannot be directly linked to disease burden without a proper risk assessment effort. Hence, no comparison is drawn here between frequency of hazard occurrence reported in the literature and disease burden estimated by FERG.

3. BEVERAGE HAZARD REVIEW

3.1. METHODOLOGY

EatSafe conducted a systematic literature review focused on peer-reviewed articles published from 2000 to 2021 that examined consumption of beverages (including water) in rural and urban communities in Ethiopia. The review followed PRISMA guidelines.[9] Appendix 1 presents the review protocol, including inclusion and exclusion criteria. The search process for this review followed the same approach for a similar EatSafe in Nigeria review on foodborne and beverage-borne hazards consumed in Nigeria (51).

Given the scarce literature on hazards in Ethiopia, hazard proxies are also included (i.e., the broader categories of pathogens that have a subset of hazards). For example, more studies on *E. coli* exist compared to toxigenic *E. coli,* although many *E. coli* strains are non-pathogenic. Similarly, bacteria that cause opportunistic human infections (e.g., *Alcaligenes* spp.,) were included. Moreover, some of these bacteria are also spoilage organisms, and while not the direct focus of the study, presence of spoilage organisms is important when planning interventions, as preventing spoilage is a major incentive for value chain actors.

3.1.1. QUALITY ASSESSMENT AND DATA EXTRACTION

Data extraction and quality assessment happened concurrently, using the same quality assessment methods from the Nigeria review (i.e., three quality categories including

[9] PRISMA refers to Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

good, medium, poor for each inclusion criterion, assessed by two Reviewers). To capture data from the studies included in this review, EatSafe used the same data extraction template developed for previous Nigeria review (see **Table 3** for types of extracted data).[10]

Table 3. *Types of data extracted during systematic review on foodborne hazards in beverages consumed in Ethiopia*

DATA EXTRACTED	CATEGORIES OF THE EXTRACTED DATA
Geographical location	Oromia, Addis Ababa, Amhara, Tigray Regions
Type of study	Cross sectional, descriptive, laboratory based cross-sectional
Name of the beverage	Raw milk, yogurt, water, fresh and packed juice
Category of the hazards	Biological, chemical
Name of the hazard	Bacteria, fungi, parasites, heavy metals
Point of sampling	Retail, point of consumption, etc.
Sampling method used	Random, purposive, composite, stratified
Diagnostic tests used	Assays, biochemical tests, Flame atomic absorption spectroscopy, culture media, multiple tube method
Samples analysed and that tested positive	Number(s)
Raw data on hazard concentration, if available	Number

3.2. FINDINGS

A total of 512 studies were retained for full text screening; of these, data were extracted from 118 publications. A summary of these data is provided in Appendix 2. The included studies yielded a total of 539 unique hazard records. Throughout this section, the number of records is used as the primary unit of information, in addition to the number of articles on a commodity/hazard pair. Because a "record" refers to the information about a commodity/hazard included in an article, an article may include multiple records (e.g., if the study targeted several hazards).

During the 20-year time period studied, there has been an increase in the number of published articles focusing on food safety in Ethiopia (see **Figure 3**)[11] – a trend mirrored in the EatSafe review on this topic in Nigeria (51).

Most studies focused on four regions within Ethiopia, with the highest in Amhara, followed by Oromia, Addis Ababa, and Tigray (**Figure 4**). Clarifying why these areas are

[10] Data on incidence rates, attack rates, death rates, DALYs, and economic impacts were not available for extraction, for almost all the papers reviewed

[11] Between 2000 and 2002, there were zero publications identified.

more prevalent in the literature was beyond the remit of this review, though large urban areas may have dominated study settings more than rural settings. Sidama, the region where Hawassa is located, was considered in six articles (nine records).

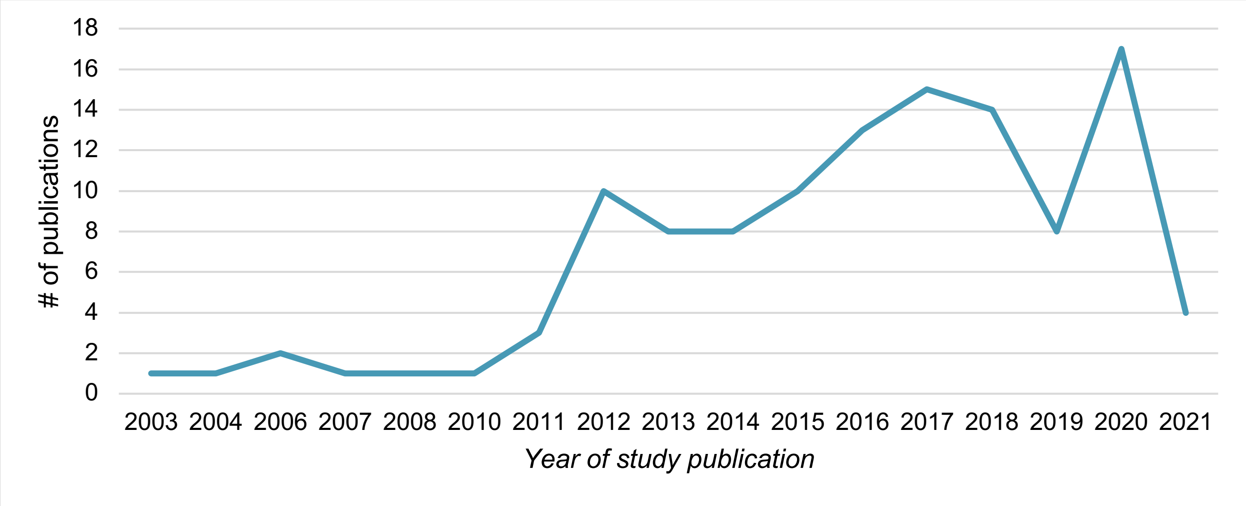

Figure 3. *Number of eligible food safety publications on beverages, by year*

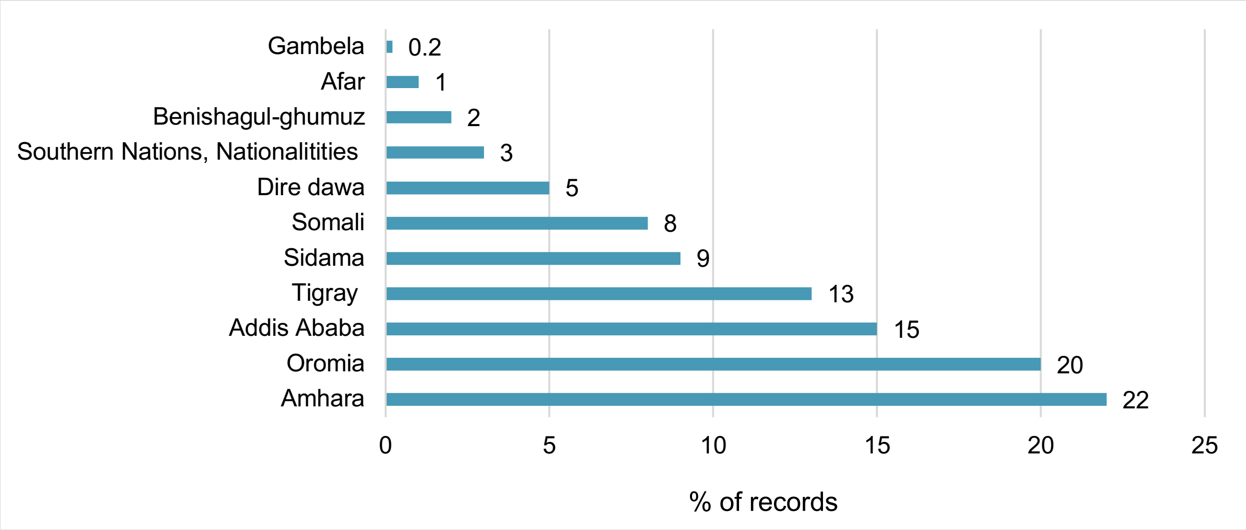

Figure 4. *Number of beverage records, by region*

3.2.1. TYPES OF BEVERAGES

Excluding alcoholic beverages, 514 records on beverages included cow and camel milk (58%), water (28%), and fruit juices (13%).[12] (**Figure 5**). Milk records (n=296) included raw milk (88%) and fermented milk (12%). Water surveys (n=142) were from tap water (55%), surface water (22%), ground water (18%), and bottled water (5%).

[12] The remaining 1% were studies examining energy drinks and were excluded from this review.

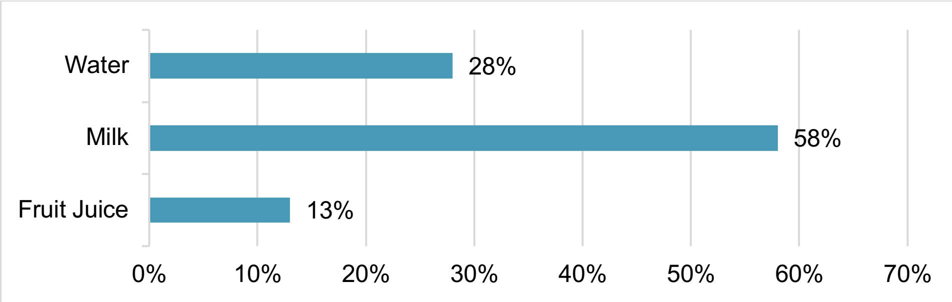

Figure 5. *Number of articles reviewed on beverages consumed in Ethiopia*

The review found both biological (n=469 records) and chemical (n=70) hazards, out of the 539 records included in the review.

3.2.2. BIOLOGICAL HAZARDS IN ALL BEVERAGES

Of the records on biological hazards or hazard proxies reported (n=469), 94% were bacteria, 5% were fungi, and 1% were parasites. Sixty-seven (15%) of the bacterial strains investigated were not hazards per se but rather provided indication of contamination or were broader categories of bacteria that also include pathogenic strains (total bacterial counts, coliforms, *Enterobacteriaceae* etc.). Also included for completeness are hazards that cause rare, opportunistic human infections such as *Alcaligenes* spp., and *Erwinia* spp. These organisms do not usually cause infections in healthy individuals, but can infect persons with compromised immune system responses, e.g. due to other infections or severe malnutrition. Of the 303 records that reported bacterial hazards, *E. coli* (21%), *Staphylococcus* spp. (22%), and *Salmonella* spp. (11%) were the most frequently reported (**Figure 6**).

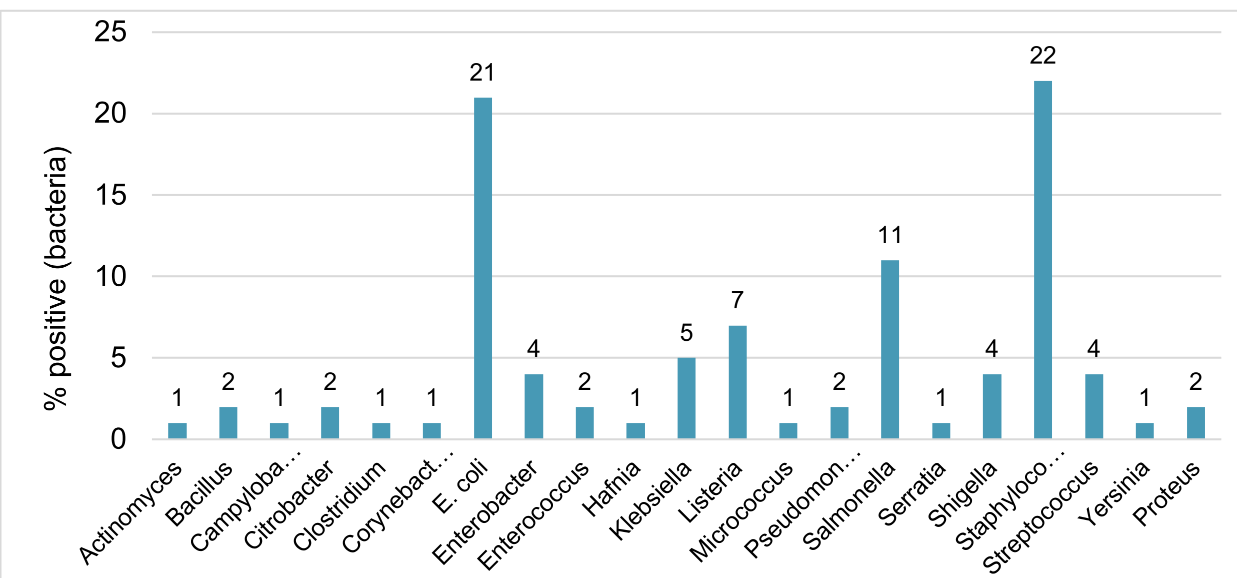

Figure 6. *Positive bacterial hazards or hazard proxies reported in beverages*

Table 4 outlines the bacterial pathogens found in beverages and associated prevalence. The presence of coliforms, an indicator of fecal pollution, was reported in water, milk, and fruit juices. For parasites, *Cryptosporidium* spp. and *Giardia* spp. were reported in water samples (as well as in fresh vegetables, see Section 2).

Table 44. *Hazard and hazard proxy occurrence by record, type of product, and source*

REF.	N*	SOURCE	BACTERIAL CONTAMINANTS, PREVALENCE AND COUNTS
BOVINE DAIRY PRODUCTS (MILK)			
(52)	n=407	Farm	*L. monocytogenes* (9%) *L. innocua* (7%) *L. seeligeri* (3%) *L. grayi, L. welshimeri,* and *L. murrayi* (each approx. 0.7%)
(53)	n=62	Farm	*Staphylococcal aureus* (11%) *E. coli* 0157:H7 (10%) *S. typhimurium* (10%) *S. enteritidis* (7%)
(54)	n=380	Vendors	*E. coli* (39%)
		Farm	*E. coli* (28%)
(55)	n=15	Street vendors	Total plate count: 8.69 Log CFU/ml
		Producers	Total plate count: 6.98 + 0.15 Log CFU/ml
	N/A	Household	*Staphylococcus* spp (24%), *Bacillus* spp (12%), *Micrococcus* spp (8%), *Pseudomonas* spp (8%), *Streptococcus* spp (5%)
(56)	n=39	Farm	Total aerobic bacterial: 4.92 Log CFU/ml
		Cooperatives	Total aerobic bacterial: 4.46 Log CFU/ml
(57)	n=86	Dairy farm	*E. coli* (31%)
		Shops	*E. coli* (63%)
(58)	n=180	Dairy farm	Bacterial count: 7.35 + 0.180 Log CFU/ml
		Shop	Bacterial count: 7.35 + 0.180 Log CFU/ml
		Cafeteria	Bacterial count: 7.42 + 0.272 Log CFU/ml, *E. coli* (44%), *Staph. aureus, Streptococcus* spp (each 26%)
(59)	n=108	Farm, transport containers at collection centers	Gram-positive staining bacteria (95%)
		Supermarket	Gram-positive staining bacteria (87%)

BOVINE DAIRY PRODUCTS (YOGURT)			
(60)	n=N/A	Farm, retail	*Staph. aureus*
(61)	n=93	Farm, retail	Aflatoxin M1
(62)	N/A	Farm cafeteria	*Staph. aureus* (22 positive samples)
(63)	n=200	Cafeteria	*Staph.*, including *S. aureus*
(15)	n=20	Farm	*Listeria* (10%)
(64)	n=20	Farm	S. aureus (0%); Coagulase negative Staph. (10%)
(65)	n=50	Supermarket, cafeteria	*Listeria* (4%)
(66)	n=18	Household, market	*E. coli* O157:H7 (44%)
(67)	n=25	Household	*Staphylococcus:* 8.6 Log CFU/ml
(68)	Varies	Retail	Multiple
(69)	n=60	Farm	*Staphylococcus:* 5.5 Log CFU/ml
(70)	n=52	Farm, retail	Total bacterial count Coliforms Enterobacteriaceae
CAMEL MILK			
(71)	n=24	Producers	*Salmonella* (66%)
		Wholesalers	*Salmonella* (83%)
(72)	n=126	Farm and Market	*Staphylococcus* spp. (90%), *Streptococcus* spp. (54%), *E. coli* (32%), *Salmonella* spp. (18%), *Klebsiella* spp. (6%), *Enterobacter* spp. (6%)
WATER			
(73)	n=25	Multiple	*E. coli* (76%)
(74)	n=125	Pipeline, water reservoir, household water containers	*E. coli* (52%) *Shigella* spp (8%), *Salmonella* (7%), *Vibrio* spp (6%)
(75)	n=70	Protected springs	*E. coli* (35%)
(76)	n=37	(Un)protected surface water sources	*Giardia* spp (14%) *Cryptosporidium* spp (3%) Both parasites (3%)
FRUIT JUICE			
(57)	n=86	Juice houses	*E. coli* (38%)

(77)	n=45	Juice houses, Cafes	*Salmonella* (20%), *Shigella* spp (24%), *S. aureus* (36%), *E. coli* (20%)
(78)	Mango (n=15), Avocado (n=17)	Juice houses	*S. aureus* (42% in mango, 20% avocado) *E coli* (26% in mango, 60% avocado) *Salmonella* spp (57% in mango, 40% avocado) *Shigella* spp (85% in mango, 20% avocado)
(79)	n=36	Juice houses	*Enterobacteriaceae*: 7.8×10^4 CFU/ml, Coliform: 6.1×10^4 CFU/ml, Fecal coliform: 0.13×10^4 CFU/ml, *S. aureus* (12%), *Enterobacter* spp. (8%), *E. coli* (7%), *Klebsiella* spp, *Enterococcus* spp. (each 5%), *B. cereus*, *Streptococcus* spp., *Serratia* spp. (each 3%)

* n = total number of samples analyzed

Although not covered in depth in the review, resistance to commonly used antibiotics was reported in some studies. For instance, *E. coli* isolated from fruit juice showed resistance to antibiotics such as clindamycin (80% of isolates), ampicillin (70%), sulfamethoxazole-trimethoprim (60%), erythromycin (60%), chloramphenicol (50%), and kanamycin (50%) (57). In a different fruit juice study, a high proportion of *E.coli* isolates were found resistant to erythromycin (100%), ceftriaxone (67%), tetracycline (67%), ciprofloxacin (60%), and chloramphenicol (50%) (77). In the same study, all *S. aureus* isolates showed resistance to erythromycin and amoxclavulic acid, and a high proportion were resistant to other antimicrobials including 18% to tetracycline, 59% to ciprofloxacin, 41% to gentamicin, and 65% to chloramphenicol (77).

3.2.3. BOVINE DAIRY PRODUCTS (MILK AND YOGURT)

Bovine dairy products are very often found to be contaminated by bacterial pathogens at various stages in production chains. This section summarizes evidence on prevalence of different pathogens, organized by beverage type (i.e., raw milk, pasteurized and raw milk combined, and yogurt).

Milk – A diverse group of bacterial hazards and pathogens were found in both raw and pasteurized milk. While 20% of samples were positive for *L. monocytogenes* (9%), *L. innocua* (7%), and *L. seeligeri* (3%) in one study (n=407) (52), another found a 34% and 3% positivity rate for *E. coli* and *E. coli O157:H7*, respectively (n=380) (54). Another study found contamination of other pathogens, including *Staphylococcus* spp. (24%) and *Bacillus* spp. (12%) (55). Other studies found lower estimates, including *E. coli* 0157:H7, *Salmonella* typhimurium, and *Staphylococcus aureus,* each present in 11% of raw milk samples (n=30) (53), as well as 20% of pasteurized milk samples containing Listeria, likely due to cross-contamination during processing (15). At the household level, rates of *E. coli* in raw milk ranged from 21% to 55% in two districts of the Oromia Region of Ethiopia (80).

In a recent study conducted in the Gondar region, almost all raw and pasteurized milk samples (95%) collected at milking, transport, processing, pasteurization, and retail levels were positive for gram-positive bacteria, including *Staphylococcus* spp, *Bacillus cereus*, and others (59). At the retail level, *E. coli* prevalence ranged from 63% in milk shops to 31% at dairy farms (57). Data on overall bacterial counts indicated significant contamination in milk samples across retail locations in Ethiopia: higher rates among street vendors compared to milk farmers (54,55), lower rates in cooperatives as compared to farmers (56), and higher rates in homes and cafeterias as opposed to dairy farms and vending shops (81).

Yogurt – Fermented milk products, in particular ergo and yogurt, were investigated by 12 studies, most of them in Oromia, Amhara, or Addis Ababa, with sample sizes ranging from 18 to 200. One study was conducted in Hawassa (69). Ergo, a cultured milk product, is produced at different conditions than yogurt, but the two products are considered as one category by several authors. Ergo or yogurt were found to be contaminated by *Staphylococcus aureus* at a 3-46% prevalence range (62,63,66) while it was not detected in a small-scale study where other Staphylococci were detected (n=20) (64). Concentrations of *Staphylococcus* spp. were not always assessed, but two studies found an average of 5.5 Log CFU/ml (69) and 8.6 Log CFU/ml (67). *Listeria* spp. was detected in 4-10% of yogurt samples (15,65) and *L. monocytogenes* in 5% (n=20) (15). When different products were compared, yogurt was contaminated at a lower frequency than cheese for both *Listeria* and *Staphylococcus* (15,62), and sometimes more (15) and sometimes less than raw milk (62)

While several studies investigated *E. coli* or coliform bacteria as hygiene indicators (66,67,69,70) only one study investigate the occurrence of pathogenic *E.coli* O157:H7, without detecting it in yogurt (n=18), while it was detected in raw cow and camel milk (66).

In terms of chemical hazards, one study (61) detected aflatoxin AFM1 in yogurt, at concentrations potentially posing health risk to children, but lower than for milk, cottage cheese, and butter.

3.2.4. CAMEL MILK

Salmonella spp. positivity rates in camel milk (n=24) varied based on value chain stage, ranging from 66% by producers, 83% in wholesalers, and 100% at retail (71). Another study found a prevalence of 90% for *Staphylococcus* spp., 54% for *Streptococcus* spp., 32% for *E. coli*, and 18% for *Salmonella* spp. (72). *Staphylococcus* had the highest prevalence at production, while *Streptococcus* prevalence increased from production to market (a trend also observed in coliform levels).

3.2.5. WATER, BY REGION

Microbial contamination has been observed in a range of water sources throughout the country. The microbial targets most often investigated are bacterial indicators of fecal contamination. This section summarizes evidence of microbial contamination in water used for drinking purposes and is organized by region. No evidence was identified from Sidama, the region where the city of Hawassa is located. Of the two neighboring regions, Oromia and the Southern Nations, some information is available for Oromia.

Oromia Region – Households water sources in the Oromia Region of Ethiopia had *E. coli* in 55% of studied samples (80). Three-quarters of river water samples and dug well water in Oromia did not comply with WHO guidelines for human drinking water standards, including *E. coli* contamination (73).[13] However, samples had higher positivity rates in the rainy season as compared to the dry season.

Amhara Region – Water samples from southern parts of Lake Tana in the Bahir Dar area contained the following pathogens: total coliforms (100%), *Clostridium perfringens* (90%), fecal coliforms (86%), and *E. coli* (82%) (82). Another study from Bahir Dar City found lower prevalence rates with samples from springs, reservoirs, and taps within households including total coliforms (21%), fecal coliforms (19%) and *E. coli* (18%) (83). In particular, *E.coli* was detected in 100% of spring water (n=4), 20% of reservoir water samples (n=10), and 17% of tap water (n=126) samples (83).

Somali Region – In Jigjiga City, water from household containers, pipeline, and reservoirs found contamination rates of 52% for *E. coli*, and rates of 6% to 8% for *Shigella* spp, *Salmonella*, and *Vibrio* spp, while half of household and pipeline water samples were positive for fecal coliforms (74). In particular, *E. coli* was detected in 55% (n=60) of household samples, and 30% (n=30), 80% (n=15), and 67% (n=15) of pipeline, reservoir, and “beyollie” (donkey cart water vendor) respectively (74).

Tigray Region – Parasites, including *Giardia* spp and *Cryptosporidium* spp, were identified in Tigray water sources (76).

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[13] WHO guidelines prescribe the absence of *E. coli* from 100 ml sample of water directly intended for human consumption.

North Gondar Zone – Over 70% of samples from urban and rural parts of the North Gondar Zone were positive for indicator bacteria, including 50% of fecal coliforms and 35% positive for *E. coli* (75).

3.2.6. FRUIT JUICES

The primary hazards identified in fresh fruit juices, including avocado, mango, papaya, and guava juices sold at cafés and juice houses include *S. aureus* (contamination rates ranging 12% to 42%), *Shigella* spp (20% to 85%), *Salmonella* spp (20% to 57%), and *E. coli* (7% to 60%), though contamination rates varied based on the type of fruit drink and geographic location (57,77–79).

3.2.7. CHEMICAL HAZARDS IN BEVERAGES

Seventy records reported on chemical hazards (13% of 539 records): heavy metals (44 records), pesticides (10), minerals (8), aflatoxins (4), and antimicrobial residues and nitrates (each 2 records). This section contains a smaller number of records than for microbial hazards and includes both drinking water sources and milk.

Aflatoxin – Bovine milk samples taken from dairy farmers in and around Addis Ababa City contained aflatoxin contamination in 26% of samples (84). In Bishoftu town, 100% of milk samples (n=108) from both industry and local producers had aflatoxin, as did yogurt samples (n=93) (61).

Antibiotic Residues – Twelve percent of milk samples from Nazareth dairy farms tested positive for Oxytetracycline and penicillin G (83% and 16% of samples tested above the recommended limit, respectively) (85). Organochlorine pesticide residues were identified in human and cow milk samples collected from South-West Ethiopia (86). Tests on drinking water samples from reservoirs and wells in Jimma City and the water treatment plant that supplies Addis Ababa, identified levels of 2,4-Dichlorophenoxyacetic acid, malathion, diazinon, and Pirimiphos-methyl (87).

Heavy Metals – In Tigray, river water samples tested for eight heavy metals were all above the respective WHO limit, including zinc (100% of samples), iron (76%), cobalt (76%), lead (64%), cadmium (44%), nickel (44%), chromium (40%), and copper (16%) (88). Another study did not find cadmium and cobalt in the tap water samples after testing, though iron, manganese, and lead levels were higher than recommended (89). Assessing the suitability of flood water for drinking, among other uses, found lead concentration levels above the WHO standard (90). Water from Lake Beseka in Oromia contained lead, cadmium, arsenic, and iron concentration levels above WHO guideline limits (91).

Fluoride – Three-quarters of river water samples and dug well water in the Oromia region did not comply with WHO guidelines for human drinking water standards, including due to high fluoride concentrations (80).

4. DISCUSSION

The two systematic review efforts presented here, synthesizing over 20 years of evidence on hazard occurrence in foods and beverages in Ethiopia, contribute to evidence-based and risk-based design of food safety interventions. The evidence points to medium-high frequency of contamination in a wide variety of foods and beverages, covering a broad range of hazards and across multiple points in the supply chains, from production to retail. Overall, the data paint a picture of widespread contamination affecting a broad range of food supply chains. The hazards detected can be transferred to food from humans, animals, or the environment. Hence, a One Health systemic approach, programmatically accounting for multiple routes of transmission (human, animal, environmental) appears warranted.

The studies covered 11 of 13 Ethiopian regions, to varying degrees; however, only a limited number of studies were conducted in Sidama, the region where the city of Hawassa -EatSafe's study site- is located (these were six studies on biological hazards in milk and fermented milk, identified by the beverage review).

Traditional markets, while playing a key role in the accessibility, quality, and safety of foods, were generally not explicitly targeted in hazard studies. However, several studies investigated foods or beverages at multiple stages along their supply chain, including at retail. For example, the studies of milk and some dairy products, where contamination was detected more frequently, included evaluation points from production to retail. This review is extremely useful to identify critical points where interventions could be beneficial and highlights the value of "farm to fork" interventions that engage multiple supply chain actors, including markets, to manage food safety hazards.

Access to safe water is critical to improving the health of a population. It is also vital for safe food handling practices. Fecal contamination of drinking water can result in cross-contamination of food or food-contact surfaces, since water is frequently used in food washing and preparation, in addition to drinking. The widespread detection of *E. coli* and coliforms in Ethiopian drinking water sources suggests many water sources have been contaminated with feces – confirming the known fecal-oral route of transmission of many waterborne and foodborne pathogens (92). In addition, the detection of *Salmonella* points to the likely role of animals as contributors to water contamination, and to the role of water in the transmission of zoonotic foodborne pathogens. Similarly, the occurrence of parasites that share human and animal hosts, such as *Giardia* spp.

and *Cryptosporidium* spp., in water highlights the need to account for both human and animal ecologies in the design of food safety interventions.

The body of evidence on chemical contaminants is scarcer than for biological hazards. Only few high-quality studies involved pesticides and aflatoxins in grains, nuts, or seeds, while none was identified in fresh fruits or vegetables. Comparatively, more studies on chemical hazards were identified for beverages, covering aflatoxins and antibiotic residues in milk, and heavy metals in drinking water sources (also potentially used to produce some beverages). However, some findings emerged: surface water may be contaminated with pesticides from nearby agricultural areas and from household application (87) which may also have persisted in the environment. Heavy metals can enter food value chains through many routes, most commonly via environmental contamination (93). The detection of this type of contaminants signals the need for systemic environmental health interventions.

The information compiled through these reviews also highlights several limitations in the available body of evidence. For instance, some hazards and commodities are clearly more studied than others. Bacterial hazards are reasonably well studied in the dairy and beef supply chains. However, data on viruses and parasites are missing. Conversely, fresh fruits and vegetables are not well studied, with only two studies (one on parasites, one on bacteria) identified by the review. This key gap supports the choice of fresh vegetables as focus commodity category for EatSafe's work. Heavy metals, the top hazard category in terms of FERG burden estimates in the sub-region including Ethiopia (5), have been investigated only in water. In addition, data are in the vast majority of studies reported as prevalence, while concentration levels are not measured. Concentrations are more often measured for chemical hazards, at least in terms of exceedance of an established threshold, while concentration is most often not measured for microbial hazards. This gap greatly hinders the ability to use these data for risk assessment purposes, hence limiting their usefulness.

Prioritizing interventions to control food safety hazards can lead to better use of scarce resources in many countries including Ethiopia (3). However, evidence-based FBD risk prioritization processes are needed to allocate resources effectively. The processes for conducting risk rankings are becoming available (94) but supporting data and the organizational capabilities to effectively implement them is often lacking. Food safety tends to capture national attention only when there is a crisis (95), especially one that is likely to result in a major public health issue or have a negative economic impact (2). Also, risk perception is often misaligned with actual risk. Diseases that most elicit fear in the population, including those that may cause a high individual burden or that are due to novel hazards, are usually regarded as more important by stakeholders, and even experts, than those that are much more common but more familiar or less dramatic in their manifestations (3).

Data on hazard occurrence along food and beverage value chains, combined with risk assessment to estimate the burden that could be expected from such occurrence, are needed to effectively prioritize how to allocate the limited resources. Ideally, risk assessment estimates (prospective) are complementary to disease surveillance data (retrospective). Disease surveillance data collection, especially when it includes disease attribution to specific hazards, can enable early detection of disease outbreaks and can be used to assess burden trends over time. These time trends provide evidence for the need of interventions, and help assess whether national-scale interventions are working. However, surveillance systems in many developing countries face a number of challenges including weak laboratory capacities and scarce resources (96,97) and have received minimal support in public health planning. Hence, in these cases, hazard occurrence and risk assessment approaches provide the best and sometimes only rigorous way to estimate the need for, and impact of interventions. The comprehensive body of evidence presented here enables this crucial assessment and highlights gaps that hinder it.

5. CONCLUSION

Multiple hazards were found to be present in varying frequencies in a broad range of foods and beverages commonly consumed in Ethiopia. From a food safety perspective this raises concern over the possible threat to public health, and merits further attention. Although a review such as this one helps gauge the prevalence of hazards which consumers may be exposed to, by itself it is not sufficient to inform risk management decisions. Data on hazard occurrence is, however, a key step in the risk assessment process – a process that includes hazard characterization, exposure assessment, and risk characterization.

In both the foodborne and beverage-borne reviews, most completed studies have not been done in systematic ways, and many are based on small sample sizes. They also tend to focus on hazards that are easy to detect, possibly due to limited laboratory resources. Further, a disproportionate number of studies were conducted in large towns or capital areas. Nationally representative samples are absent, and hazard proxies were often examined rather than the hazards themselves. Therefore, comparing or aggregating studies is difficult. Nonetheless, it is clear that common, detrimental hazards are very high in food and beverages consumed in Ethiopia, leading to an almost certain conclusion of a high burden of FBD – a conclusion consistent with findings from the FERG.

Valuable insights emerge from the review synthesizing evidence on foodborne hazards in Ethiopia, including:

- Across commodities, bacterial hazards are the most studied (70%), but not in all commodities; parasites were the focus of some studies (20%), particularly on fresh fruits and vegetables, while only a minority of studies addressed viruses or chemical hazards.
- The beef value chain is the most intensely studied commodity, in particular for bacterial hazards.
- Few studies focused on eggs or cheese, and all assessed bacterial contamination as the most common hazard found in these products.
- Few studies on microbial contamination in fresh vegetables were identified, the majority investigated parasites, with a few for bacteria, and none for viruses.
- Several studies measured contamination at multiple nodes of a supply chain, including retail, providing actionable evidence on potential control points. In particular contamination in some supply chains was observed to increase going from production to retail. While we cannot readily draw conclusions on trends along the supply chain without a meta-analysis, such trends would support the argument that significant risk reduction could be achieved in the later stages of the chain, including at markets.
- While the reasons for the strong focus on assessing bacterial contamination are not known, this focus is consistent with FERG estimates that bacteria are the leading cause of foodborne disease in the African region that includes Ethiopia.

The novel review on hazards detected in beverages adds an important dimension to currently available evidence on foodborne contamination. Key insights include:

- Studies reviewed had a strong geographical bias, with some areas in the country being poorly represented.
- Recent trends show an increase in literature published on hazards in beverages in Ethiopia.
- Overall, bacterial hazards were the most commonly investigated. Other hazards appeared less frequently in the literature despite some of them carrying important health implications, e.g. heavy metals. Evidence on parasitic hazards is lacking.
- Milk is fairly well studied, while evidence is lacking for other beverages.
- The high contamination levels observed in water can be seen as a proxy for the level of environmental contamination in an area, with repercussions on foods grown and processed there.

- Contamination in water also highlights the importance of applying a One Health approach for food safety interventions, given the animal and human sources of water contamination.
- Given the home-made, traditional nature of some of the beverages studied in this review, care must be taken to identify and engage stakeholder in informal value chains.

Across all studies, and also considering the FERG burden estimates, the most important foodborne hazards appear to be *Salmonella*, enterotoxigenic *E. coli*, and *Campylobacter* spp. with probable additions of *Staphylococcus* spp., lead, and *Listeria*. Other hazards may be equally or more problematic but are not represented in published studies.

This review will inform the choice of specific hazard(s) and commodities to target in EatSafe's risk assessment activity in Ethiopia. Through the risk modelling process, the risk associated with consumption of selected foods will be determined, and potential mitigation steps identified and discussed.

Recommendations for Intervention Design and Future Studies under EatSafe

These reviews have outlined food hazard occurrence in beverages and foods in Ethiopia, based on past research. Based on the results of this activity, , we recommend that EatSafe considers the following points while planning for the risk assessment (Activity ET 1.6) that informs intervention design:

- Several hazard types were reported in the review, many not in the list of priorities determined by FERG. This might suggest a (potential focus on the “trivial many” rather than the “vital few” in the literature, which can be misleading.
- Although the study provides a comprehensive overview of the status of hazards occurrence in foods and beverages in Ethiopia, it is not, on its own, sufficient to inform food safety prioritization decisions; these data can, however, contribute to risk assessment and risk ranking efforts.
- Fresh fruits and vegetables are not well studied. This key gap supports the choice of fresh vegetables as focus commodity category for EatSafe’s work.
- Other important data gaps include viral pathogens, parasites, and eggs.
- No clear evidence exists to assess the role of market practices or infrastructure in either hazard control or enabling/exacerbating contamination.
- The vast majority of studies did not measure concentration, only presence/absence (summarized as prevalence, i.e. frequency of detection). This key gap hinders the usefulness of these data for risk assessment.
- Where possible, the risk assessment modeling should utilize primary data collected within the project, due to significant gaps in the literature.
- Overall, the widespread bacterial contamination observed in a broad range of foods and beverages points to the likely role of environmental and zoonotic transmission, which calls for a One Health systemic approach.

6. REFERENCES

1. FAO. The future of food safety. 2019.
2. WHO. WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015 [Internet]. Geneva: World Health Organization; 2015 [cited 2021 Nov 15]. 255 p. Available from: https://apps.who.int/iris/handle/10665/199350
3. Grace D, Alonso S, Mutua F, Roesel K, Lindahl J, Amenu K. Food safety investment expert advice: Burkina Faso, Ethiopia, Nigeria. 2018;72.
4. Havelaar AH, Kirk MD, Torgerson PR, Gibb HJ, Hald T, Lake RJ, et al. World Health Organization Global Estimates and Regional Comparisons of the Burden of Foodborne Disease in 2010. von Seidlein L, editor. PLOS Med. 2015 Dec 3;12(12):e1001923.
5. Gibb HJ, Barchowsky A, Bellinger D, Bolger PM, Carrington C, Havelaar AH, et al. Estimates of the 2015 global and regional disease burden from four foodborne metals – arsenic, cadmium, lead and methylmercury. Environ Res. 2019 Jul;174:188–94.
6. Dhakal A, Sbar E. Aflatoxin Toxicity. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Feb 1]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK557781/
7. Beyene T, Hayishe H, Gizaw F, Beyi AF, Abunna F, Mammo B, et al. Prevalence and antimicrobial resistance profile of Staphylococcus in dairy farms, abattoir and humans in Addis Ababa, Ethiopia. BMC Res Notes [Internet]. 2017 Dec [cited 2021 Nov 26];10(1):171. Available from: http://bmcresnotes.biomedcentral.com/articles/10.1186/s13104-017-2487-y
8. Tigabu E, Asrat D, Kassa T, Sinmegn T, Molla B, Gebreyes W. Assessment of Risk Factors in Milk Contamination with Staphylococcus aureus in Urban and Peri-Urban Small-Holder Dairy Farming in Central Ethiopia. Zoonoses Public Health. 2015 Dec;62(8):637–43.
9. Daka D, G/silassie S, Yihdego D. Antibiotic-resistance Staphylococcus aureus isolated from cow's milk in the Hawassa area, South Ethiopia. Ann Clin Microbiol Antimicrob. 2012;11(1):26.
10. Addis Z, Kebede N, Sisay Z, Alemayehu H, Wubetie 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 Dec;11(1):222.
11. Ashenafi M. Microbiological quality of Ayib, a traditional Ethiopian cottage cheese. International Journal of Food Microbiologo. 1990;10:263–8.
12. Garedew L, Taddese A, Biru T, Nigatu S, Kebede E, Ejo M, et al. Prevalence and antimicrobial susceptibility profile of listeria species from ready-to-eat foods of animal origin in Gondar Town, Ethiopia. BMC Microbiol. 2015;1(15).
13. Gebretsadik S, Kassa T, Alemayehu H, Huruy K, Kebede N. Isolation and characterization of Listeria monocytogenes and other Listeria species in foods of animal origin in Addis Ababa, Ethiopia. J Infect Public Health. 2011 Mar;4(1):22–9.
14. Molla B, Yilma R, Alemayehu D. Listeria monocytogenes and other Listeria species in retail meat and milk products in Addis Ababa, Ethiopia. EthiopJHealth Dev 2. 2004;18(3).

15. Seyoum ET, Woldetsadik DA, Mekonen TK, Gezahegn HA, Gebreyes WA. Prevalence of Listeria monocytogenes in raw bovine milk and milk products from central highlands of Ethiopia. J Infect Dev Ctries. 2015 Nov 30;9(11):1204–9.

16. Ejo M, Garedew L, Alebachew Z, Worku W. Prevalence and Antimicrobial Resistance of Salmonella Isolated from Animal-Origin Food Items in Gondar, Ethiopia. BioMed Res Int. 2016;2016:1–8.

17. Fetene T, Kebede N, Alem G. Tuberculosis Infection in Animal and Human Populations in Three Districts of Western Gojam, Ethiopia. Zoonoses Public Health. 2011;58(1):47–53.

18. Ameni G, Erkihun A. Bovine tuberculosis on small-scale dairy farms in Adama Town, central Ethiopia, and farmer awareness of the disease. Rev Sci Tech Int Off Epizoot. 2007 Dec;26(3):711–9.

19. Elias K, Hussein D, Asseged B, Wondwossen T, Gebeyehu M. Status of bovine tuberculosis in Addis Ababa dairy farms. Rev Sci Tech Int Off Epizoot. 2008 Dec 1;27(3):915–23.

20. Edget A, Shiferaw D, Mengistu S. Microbial safety and its public health concern of E. coli O157:H7 and Salmonella spp. in beef at Dire Dawa administrative city and Haramaya University, Ethiopia. J Vet Med Anim Health. 2017 Aug;9(8):213–27.

21. Azage M, Kibret M. The Bacteriological Quality, Safety, and Antibiogram of Salmonella Isolates from Fresh Meat in Retail Shops of Bahir Dar City, Ethiopia. 2017; Available from: https://doi.org/10.1155/2017/4317202

22. Bersisa A, Tulu D, Negera C. Investigation of Bacteriological Quality of Meat from Abattoir and Butcher Shops in Bishoftu, Central Ethiopia. Int J Microbiol. 2019;2019.

23. Gebremedhin EZ, Soboka GT, Borana BM, Marami LM, Sarba EJ, Tadese ND, et al. Prevalence, risk factors, and antibiogram of nontyphoidal Salmonella from beef in Ambo and Holeta towns, Oromia region, Ethiopia. Int J Microbiol. 2021;2021.

24. Gutema FD, Rasschaert G, Agga GE, Merera O, Duguma AB, Abdi RD, et al. Prevalence, Antimicrobial Resistance, and Molecular Characterization of Salmonella in Cattle, Beef, and Diarrheic Patients in Bishoftu, Ethiopia. Foodborne Pathog Dis. 2021;18(4):283–9.

25. Kore K, Asrade B, Demissie K, Aragaw K. Characterization of Salmonella isolated from apparently healthy slaughtered cattle and retail beef in Hawassa, southern Ethiopia. Prev Vet Med. 2017;147(August):11–6.

26. Wabeto W, Abraham Y, Anjulo AA. Detection and identification of antimicrobial-resistant Salmonella in raw beef at Wolaita Sodo municipal abattoir, Southern Ethiopia. J Health Popul Nutr. 2017;36(1):1–8.

27. Gebremedhin EZ, Hirpa G, Borana BM, Sarba EJ, Marami LM, Kelbesa KA, et al. Listeria species occurrence and associated factors and antibiogram of listeria monocytogenes in beef at abattoirs, butchers, and restaurants in ambo and holeta in Ethiopia. Infect Drug Resist. 2021;14(April):1493–504.

28. Hiko A, Asrat D, Zewde G. Occurrence of Escherichia coli O157:H7 in retail raw meat products in Ethiopia. J Infect Dev Ctries. 2008 Oct 1;2(5):389–93.

29. Tadese ND, Gebremedhi EZ, Moges F, Borana BM, Marami LM, Sarba EJ, et al. Occurrence and antibiogram of escherichia coli O157:H7 in raw beef and hygienic practices in abattoir and retailer shops in ambo town, ethiopia. Vet Med Int. 2021;2021.

30. Sebsibe MA, Asfaw ET. Occurrence of multi-drug resistant escherichia coli and escherichia coli o157:H7 in meat and swab samples of various contact surfaces at abattoir and butcher shops in Jimma town, southwest district of Ethiopia. Infect Drug Resist. 2020;13:3853–62.

31. Gutema FD, Rasschaert G, Agga GE, Jufare A, Duguma AB, Abdi RD, et al. Occurrence, Molecular Characteristics, and Antimicrobial Resistance of Escherichia coli O157 in Cattle, Beef, and Humans in Bishoftu Town, Central Ethiopia. Foodborne Pathog 2021. 2021;

32. Beyi AF, Fite AT, Tora E, Tafese A, Genu T, Kaba T, et al. Prevalence and antimicrobial susceptibility of Escherichia coli O157 in beef at butcher shops and restaurants in central Ethiopia. BMC Microbiol. 2017 Dec;17(1):49.

33. Abdissa R, Haile W, Fite AT, Beyi AF, Agga GE, Edao BM, et al. Prevalence of Escherichia coli O157: H7 in beef cattle at slaughter and beef carcasses at retail shops in Ethiopia. BMC Infect Dis. 2017;17(1):1–7.

34. Garedew L, Hagos Z, Zegeye B, Addis Z. The detection and antimicrobial susceptibility profile of Shigella isolates from meat and swab samples at butchers' shops in Gondar town, Northwest Ethiopia. J Infect Public Health. 2016 Jun;9(3):348–55.

35. Tsehayneh B, Yayeh T, Agmas B. Evaluation of bacterial load and antibiotic resistance pattern of staphylococcus aureus from ready-to-eat raw beef in Bahir Dar City, Ethiopia. Int J Microbiol. 2021;2021.

36. Aylate A, Shah SN, Aleme H, Gizaw TT. Bovine tuberculosis: prevalence and diagnostic efficacy of routine meat inspection procedure in Woldiya municipality abattoir north Wollo zone, Ethiopia. Trop Anim Health Prod. 2013 Mar;45(3):855–64.

37. Bayu Z, Asrade B, Kebede N, Sisay Z, Bayu Y. Identification and characterization of Salmonella species in whole egg purchased from local markets in Addis Ababa, Ethiopia. J Vet Med Anim Health. 2013 May 31;5(5):133–7.

38. Muleta D, Ashenafi M. Salmonella, Shigella and growth potential of other food-borne pathogens in Ethiopian street vended foods. East Afr Med J. 2001 Nov;78(11):576–80.

39. Taddese D, Tolosa T, Deresa B, Lakow 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(1):1–7.

40. Bekele F, Tefera T, Biresaw G, Yohannes T. Parasitic contamination of raw vegetables and fruits collected from selected local markets in Arba Minch town, Southern Ethiopia. Infect Dis Poverty. 2017 Dec;6(1):19.

41. Alemu G, Nega M, Alemu M. Parasitic Contamination of Fruits and Vegetables Collected from Local Markets of Bahir Dar City, Northwest Ethiopia. Res Rep Trop Med. 2020;11:17–25.

42. Guchi B, Ashenafi M. Microbial load, prevalence and antibiograms of salmonella and Shigella in lettuce and green peppers. Ethiop J Health Sci. 2010 Mar;20(1):41–8.

43. Haile AF, Alonso S, Berhe N, Bekele Atoma T, Boyaka PN, Grace D. Escherichia coli O157:H7 in Retail Lettuce (Lactuca sativa) in Addis Ababa City: Magnitude of Contamination and Antimicrobial Susceptibility Pattern. Front Microbiol. 2021;12:694506.

44. Kifleyohannes T, Debenham JJ, Robertson LJ. Is fresh produce in Tigray, Ethiopia a potential transmission vehicle for cryptosporidium and giardia? Foods. 2021;10(9):1–12.

45. Ayalew A, Fehrmann H, Lepschy J, Beck R, Abate D. Natural occurrence of mycotoxins in staple cereals from Ethiopia. Mycopathologia. 2006 Jul;162(1):57–63.

46. Mohammed A, Chala A, Dejene M, Fininsa C, Hoisington DA, Sobolev VS, et al. Aspergillus and aflatoxin in groundnut (Arachis hypogaea L.) and groundnut cake in Eastern Ethiopia. Food Addit Contam Part B Surveill. 2016 Dec;9(4):290–8.

47. Getachew A, Chala A, Hofgaard IS, Brurberg MB, Sulyok M, Tronsmo AM. Multimycotoxin and fungal analysis of maize grains from south and southwestern Ethiopia. Food Addit Contam Part B Surveill. 2018;11(1):64–74.

48. Mekonnen B, Siraj J, Negash S. Determination of Pesticide Residues in Food Premises Using QuECHERS Method in Bench-Sheko Zone, Southwest Ethiopia. BioMed Res Int. 2021 Mar 20;2021:e6612096.

49. EU Pesticides Database (v.2.2) Active substance [Internet]. [cited 2022 Mar 8]. Available from: https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/active-substances/?event=as.details&as_id=600

50. Pesticide Database | CODEXALIMENTARIUS FAO-WHO [Internet]. [cited 2022 Mar 8]. Available from: https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/en/

51. Oduori DO, Kwoba E, Thomas L, Grace D, Mutua F. Assessment of Foodborne Disease Hazards in Beverages Consumed in Nigeria: A Systematic Literature Review. Foodborne Pathog Dis [Internet]. 2021 Sep 16 [cited 2021 Dec 6];fpd.2021.0043. Available from: https://www.liebertpub.com/doi/10.1089/fpd.2021.0043

52. Girma Y, Abebe B. Isolation, Identification and Antimicrobial Susceptibility of Listeria Species from Raw Bovine Milk in Debre-Birhan Town, Ethiopia. 2018;7.

53. Mekuria A, Beyene T. Zoonotic Bacterial Pathogens Isolated from Food of Bovine in Selected Woredas of Tigray , Ethiopia. 2014;31(11):1864–8.

54. Disassa N, Sibhat B, Mengistu S, Muktar Y, Belina D. Prevalence and Antimicrobial Susceptibility Pattern of E. coli O157:H7 Isolated from Traditionally Marketed Raw Cow Milk in and around Asosa Town, Western Ethiopia. Vet Med Int. 2017;2017:1–7.

55. Worku D, Seifu E, Bultosa G. Handling Practices and Safety of Street-Vended Milk in and Around Addis Ababa City. Curr Nutr Food Sci. 2014;10(2):156–62.

56. Tekliye M, Gizaw M. Handling Practices, Evaluation of Adulteration and Microbial Quality of Raw Cow Milk around Bahir Dar, Ethiopia. Food Sci Qual Manag. 2017;61(Volume 61):25–33.

57. Tadesse HA, Gidey NB, Workelule K, Hailu H, Gidey S, Bsrat A, et al. Antimicrobial Resistance Profile of E. coli Isolated from Raw Cow Milk and Fresh Fruit Juice in Mekelle, Tigray, Ethiopia. Vet Med Int. 2018;2018.

58. Shunda D, Habtamu T, Endale B. Assessment of bacteriological quality of raw cow milk at different critical points in Mekelle, Ethiopia. Int J Livest Res. 2013;3(4):42–8.

59. Garedew L, Mengesha D, Birhanu A, Mohammed A. Diverse Gram-positive bacteria identified from raw and pasteurized cow milk consumed at Gondar town and its environs, Ethiopia. Ethiop Vet J. 2015;19(1):49.

60. Makita K, Desissa F, Teklu A, Zewde G, Grace D. Risk assessment of staphylococcal poisoning due to consumption of informally-marketed milk and home-made yoghurt in Debre Zeit, Ethiopia. Int J Food Microbiol. 2012;153(1–2):135–41.

61. Tadesse S, Berhanu T, Woldegiorgis AZ. Aflatoxin M1 in milk and milk products marketed by local and industrial producers in Bishoftu town of Ethiopia. Food Control. 2020;118(May):107386.

62. Weldeselassie M, Gugsa G, Kumar A, Tsegaye Y, Awol N, Ahmed M, et al. Isolation and Characterization of Staphylococcus aureus From Food of Bovine Origin in Mekelle, Tigray, Ethiopia. Open Microbiol J. 2020;14(1):234–41.

63. Argaw S, Addis M, Degefu H. Identification and Antimicrobial Resistance Pattern of Staphylococci Isolated From Cottage Cheese (Ayib) and Yoghurt (Ergo) in Selected Districts of Jimma Zone, Ethiopia. Health Sci J. 2018;12(1):1–8.

64. Tigabu E, Asrat D, Kassa T, Sinmegn T, Molla B, Gebreyes W. Assessment of Risk Factors in Milk Contamination with Staphylococcus aureus in Urban and Peri-Urban Small-Holder Dairy Farming in Central Ethiopia. Zoonoses Public Health. 2015 Dec;62(8):637–43.

65. Muhammed W, Muleta D, Deneke Y, Gashaw A, Bitew. Species in Milk and Milk Products in Retail Market. Asian J Dairy Food Res. 2013;32(1):35–9.

66. Amenu K, Grace D, Nemo S, Wieland B. Bacteriological quality and safety of ready-to-consume milk and naturally fermented milk in Borana pastoral area, southern Ethiopia. Trop Anim Health Prod. 2019;51(7):2079–84.

67. Mamo J, Kumera B, Asmamaw M. Evaluation of microbiological quality of raw milk, homemade Ergo and homemade Ayib in North Shoa District, Amhara, Ethiopia. Pak J Food Sci. 2016;26(2):83–91.

68. Yilma Z. Microbial Properties of Ethiopian Marketed Milk and Milk Products and Associated Critical Points of Contamination: An Epidemiological Perspective. Epidemiol Insights. 2012;(April 2012).

69. Yigrem S. Assessment of Microbial Quality and Safety of a Traditional Fermented Milk-Irgo, Collected from Hawassa City, South Ethiopia. J Food Process Technol. 2015;06(03):1–6.

70. Yilma Z, Faye B, Loiseau G. Occurrence and distribution of species of Enterobacteriaceae in selected Ethiopian traditional dairy products: A contribution to epidemiology. Food Control. 2007 Nov;18(11):1397–404.

71. Adugna M, Seifu E, Kebeded A, Doluschitz R. Quality and safety of camel milk along the value chain in eastern Ethiopia. Int J Food Stud. 2013;2(2):150–7.

72. Abera T, Legesse Y, Mummed B, Urga B. Bacteriological quality of raw camel milk along the market value chain in Fafen zone, Ethiopian Somali regional state. BMC Res Notes [Internet]. 2016 Dec [cited 2021 Nov 26];9(1):285. Available from: http://bmcresnotes.biomedcentral.com/articles/10.1186/s13104-016-2088-1

73. Amenu K, Markemann A, Valle Zárate A. Water for human and livestock consumption in rural settings of Ethiopia: Assessments of quality and health aspects. Environ Monit Assess. 2013;185(11):9571–86.

74. Asfaw HS, Reta MA, Yimer FG. High enteric bacterial contamination of drinking water in Jigjiga city, Eastern Ethiopia. Ethiop J Health Dev. 2016;30(3):118–28.

75. Admassu M, Wubshet M, Gelaw B. A survey of bacteriological quality of drinking water in North Gondar. Ethiop J Health Dev [Internet]. 2004 [cited 2021 Nov 26];18(2). Available from: http://www.ajol.info/index.php/ejhd/article/view/9946

76. Kifleyohannes T, Robertson LJ. Preliminary insights regarding water as a transmission vehicle for Cryptosporidium and Giardia in Tigray, Ethiopia. Food Waterborne Parasitol. 2020;19.

77. Kebede H, Hadush H, Gebrecherkos T, Chaithanya KK. Public health risks and bacterial safety of fruit juices prepared in Axum town, north Ethiopia. J Pharm Res. 2018;12(4):8.

78. Haileselassie M, Taddele H, Adhana K. Source(s) of contamination of 'raw' and 'ready-to-eat' foods and their public health risks in Mekelle City, Ethiopia. 2012;2(2):20–9.

79. Geta K, Kebede A, Chemedissa M. Microbiological Safety of Fruit Juices Consumed in Cafes and Restaurants of Debre-Markos Town , North Western Ethiopia. Preprints. 2018;2018060027(June).

80. Amenu K, Spengler M, Markemann A, Zárate AV. Microbial quality of water in rural households of Ethiopia: Implications for milk safety and public health. J Health Popul Nutr. 2014;32(2):190–7.

81. Dingeta S, Tassew H, Balcha E. Assessment of Bacteriological Quality of Raw cow milk at Different Critical Points in Mekelle, Ethiopia -. Int J Livest Res. 2013;3(4):42–8.

82. Goshu G, Byamukama D, Manafi M, Kirschner AKT, Farnleitner AH. A pilot study on anthropogenic faecal pollution impact in Bahir Dar Gulf of Lake Tana, Northern Ethiopia. Ecohydrol Hydrobiol. 2010 Jan;10(2–4):271–9.

83. Abera B, Kibret M, Goshu G, Yimer M. Bacterial quality of drinking water sources and antimicrobial resistance profile of Enterobacteriaceae in Bahir Dar city, Ethiopia. J Water Sanit Hyg Dev. 2014 Sep 1;4(3):384–90.

84. Gizachew D, Szonyi B, Tegegne A, Hanson J, Grace D. Aflatoxin contamination of milk and dairy feeds in the Greater Addis Ababa milk shed, Ethiopia. Food Control. 2016 Jan;59:773–9.

85. Abebew D, Belihu K, Zewde G. Detection and determination of Oxytetracycline and Penicillin G antibiotic residue levels in bovine bulk milk from Nazareth dairy farms, Ethiopia. 2014;15.

86. Gebremichael S, Birhanu T, Tessema DA. Analysis of organochlorine pesticide residues in human and cow's milk in the towns of Asendabo, Serbo and Jimma in South-Western Ethiopia. Chemosphere. 2013 Feb;90(5):1652–7.

87. Mekonen S, Argaw R, Simanesew A, Houbraken M, Senaeve D, Ambelu A, et al. Pesticide residues in drinking water and associated risk to consumers in Ethiopia. Chemosphere. 2016 Nov;162:252–60.

88. Haftu Z, Estifanos S. Investigation of physico-chemical Characteristics and Heavy Metals Concentration Implying to the Effect of Local Geology on Surface Water Quality of Werii Catchment, Tigray, Ethiopia. EQA - Int J Environ Qual. 2020 May 12;40:11-18 Pages.

89. Dessie BK, Gari SR, Mihret A, Desta AF, Mehari B. Determination and health risk assessment of trace elements in the tap water of two Sub-Cities of Addis Ababa, Ethiopia. Heliyon. 2021 May;7(5):e06988.

90. Berhe S, Leta S. Suitability Assessment of Water Quality of Assabol Dam for Irrigation, Fish Culture and Drinking Purposes at Erob Wereda, Eastern Tigray; Ethiopia. 2013;4(3):7.

91. Fuad A, Gelaneh W. Determination of heavy metals concentrations within the ever growing Lake Baseka, Ethiopia using spectrophotometric technique. Afr J Environ Sci Technol. 2017 Mar 31;11(3):146–50.

92. Hiko A, Muktar Y. Levels of microbial contamination in non-alcoholic beverages from selected eastern Ethiopian towns markets. Sci Afr [Internet]. 2020 Mar [cited 2021 Nov 26];7:e00223. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2468227619307847

93. Witkowska D, Słowik J, Chilicka K. Heavy Metals and Human Health: Possible Exposure Pathways and the Competition for Protein Binding Sites. Molecules. 2021;26(6060).

94. FAO. FAO Guide to Ranking Food Safety Risks at the National Level [Internet]. Food and Agriculture Organization of the United Nations; 2020. (Food Safety and Quality Series). Available from: http://www.fao.org/documents/card/en/c/cb0887en

95. Jaffee S, Henson S, Unnevehr L, Grace D, Cassou E. The Safe Food Imperative: Accelerating Progress in Low-And Middleincome Countries. 2019;211.

96. Phalkey RK, Yamamoto S, Awate P, Marx M. Challenges with the implementation of an Integrated Disease Surveillance and Response (IDSR) system: systematic review of the lessons learned. Health Policy Plan. 2015 Feb 1;30(1):131–43.

97. May L, Chretien J-P, Pavlin JA. Beyond traditional surveillance: applying syndromic surveillance to developing settings – opportunities and challenges. BMC Public Health. 2009 Dec;9(1):242.

98. Gizaw F, Kekeba T, Teshome F, Kebede M, Abreham T, Hayishe H, et al. Distribution and antimicrobial resistance profile of coagulase-negative staphylococci from cattle, equipment, and personnel on dairy farm and abattoir settings. Heliyon. 2020 Mar;6(3):e03606.

99. Bekele F, Shumbej T. Fruit and vegetable contamination with medically important helminths and protozoans in Tarcha town, Dawuro zone, South West Ethiopia. 2019; Available from: http://doi.org/10.2147/RRTM.S205250

100. Alemayehu TA, Weldetinsae A, Dinssa DA, Derra FA, Bedada TL, Asefa YB, et al. Sanitary condition and its microbiological quality of improved water sources in the Southern Region of Ethiopia. Environ Monit Assess. 2020;192(5).

101. Edessa N, Geritu N, Mulugeta K. Microbiological assessment of drinking water with reference to diarrheagenic bacterial pathogens in Shashemane Rural District, Ethiopia. Afr J Microbiol Res. 2017;11(6):254–63.

102. Yasin M, Ketema T, Bacha K. Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia. BMC Res Notes. 2015;8(1):1–13.

103. Gebrewahd A, Adhanom G, Gebremichail G, Kahsay T, Berhe B, Asfaw Z, et al. Bacteriological quality and associated risk factors of drinking water in Eastern zone, Tigrai, Ethiopia, 2019. Trop Dis Travel Med Vaccines. 2020 May;6(1):15.

104. Yenew C, Kebede M, Mulat M. Antimicrobial-Resistance Pathogen Load and Public Health Risk of Drinking Water in South Gondar, Ethiopia. 2020;1–14.

105. Olbasa BW. Characterization of Physicochemical Water Quality Parameters of River Gudar (Oromia region, West Shewa Zone, Ethiopia) for Drinking Purpose. IOSR J Appl Chem. 2017;10(05):47–52.

106. Haftu Z, Sathishkumar P. Determination of Physicochemical Parameters and Heavy Metals Concentration in Drinking Water at Asgede Tsimbila District, Tigray, Ethiopia. Chem Afr. 2020;3(2):419–26.

107. Alemu T, Mulugeta E, Tadese M. Determination of physicochemical parameters of “Hora” natural mineral water and soil in Senkele Kebele, Oromia Region, Ethiopia. Cogent Chem. 2017;3(1):1354800.

108. Ali H, Ed B, Bacha K, Ketema T. Bacteriological Quality and antimicrobial susceptibility of some isolates of Well Water used for Drinking in Jimma Town, Southwest Ethiopia. Ethiop J Educ Sci. 2011;6(2):95–108.

109. Abera B, Kibret M, Mulu W. Extended-spectrum beta (β)-lactamases and antibiogram in enterobacteriaceae from clinical and drinking water sources from bahir dar city, Ethiopia. PLoS ONE. 2016;11(11):1–10.

110. Berhanu A. Bacteriological and Physicochemical Quality of Drinking Water Sources and Household Water Handling Practice Among Rural Communities of Bona District, Sidama Zone-Zouthern, Ethiopia. Sci J Public Health. 2015;3(5):782.

111. Leta SBS. Suitability Assessment of Water Quality of Assabol Dam for Irrigation, Fish Culture and Drinking Purposes at Erob Wereda, Eastern Tigray; Ethiopia. Int J Sci Res IJSR. 2015;4(3):1388–94.

112. Debebe D, Behulu F, Getaneh Z. Predicting children’s blood lead levels from exposure to school drinking water in Addis Ababa, Ethiopia. J Water Health. 2020;18(4):595–601.

113. Debela TH, Beyene A, Tesfahun E, Getaneh A, Gize A, Mekonnen Z. Fecal contamination of soil and water in sub-Saharan Africa cities: The case of Addis Ababa, Ethiopia. Ecohydrol Hydrobiol. 2018;18(2):225–30.

114. Girmay AM, Gari SR, Gebremariam AG, Alemu BM, Evans MR, Gessew GT. Longitudinal study of microbial load of drinking water and seasonal variation of water quality at the point of use in food establishments of addis ababa, ethiopia. J Water Sanit Hyg Dev. 2020;10(4):969–78.

115. Hizkeal T. Atomic Absorption Spectroscopic Determination of Heavy Metal Concentrations in Kulufo River, Arbaminch, Gamo Gofa, Ethiopia. J Environ Anal Chem. 2016;03(01).

116. Gizachew M, Admasie A, Wegi C, Assefa E. Bacteriological Contamination of Drinking Water Supply from Protected Water Sources to Point of Use and Water Handling Practices among Beneficiary Households of Boloso Sore Woreda, Wolaita Zone, Ethiopia. Int J Microbiol. 2020;2020.

117. Mebrahtu G, Zerabruk S. Concentration and Health Implication of Heavy Metals in Drinking Water from Urban Areas of Tigray Region, Northern Ethiopia. Momona Ethiop J Sci. 2011;3(1).

118. Tadesse M, Tsegaye D, Girma G. Assessment of the level of some physico-chemical parameters and heavy metals of Rebu river in oromia region, Ethiopia. MOJ Biol Med. 2018;3(3):99–118.

119. Haji M, Karuppannan S, Qin D, Shube H, Kawo NS. Potential Human Health Risks Due to Groundwater Fluoride Contamination: A Case Study Using Multi-techniques Approaches (GWQI, FPI, GIS, HHRA) in Bilate River Basin of Southern Main Ethiopian Rift, Ethiopia. Arch Environ Contam Toxicol. 2021 Jan 1;80(1):277–93.

120. Merola RB, Kravchenko J, Rango T, Vengosh A. Arsenic exposure of rural populations from the Rift Valley of Ethiopia as monitored by keratin in toenails. J Expo Sci Environ Epidemiol. 2014;24(2):121–6.

121. Reimann C, Bjorvatn K, Frengstad B, Melaku Z, Tekle-Haimanot R, Siewers U. Drinking water quality in the Ethiopian section of the East African Rift Valley I - Data and health aspects. Sci Total Environ. 2003 Jul 20;311(1–3):65–80.

122. Shishaye HA. Diagnosing the Suitability of Lake Water for Domestic and Agricultural Uses: A Case Study in Eastern Ethiopia. East Afr J Sci. 2018;12(2):101–10.

123. Temam MrK, Rao PVVP, prasad CHD. Microbial Qualities of Drinking Water and Its Public Health Implication in the Case of Adama City, Ethiopia. Ethiop J Sci Sustain Dev. 2019;6(1):1–13.

124. Siraj K, Kitte SA. Analysis of Copper, Zinc and Lead using Atomic Absorption Spectrophotometer in ground water of Jimma town of Southwestern Ethiopia. Int J Chem Anal Sci. 2013;4(4):201–4.

125. Zinabu Tebeje Zewdu. Determination of ground water quality of former Lake Haramaya, Oromia Regional State, Ethiopia. J Ecol Nat Environ. 2012;4(7).

126. Teklay A, Amare M. Water quality characteristics and pollution levels of heavy metals in Lake Haiq, Ethiopia. Ethiop J Sci Technol. 2015;8(1):15.

127. Bedada TL, Mezemir WD, Dera FA, Sima WG, Gebre SG, Edicho RM, et al. Virological and bacteriological quality of drinking water in Ethiopia. Appl Water Sci. 2018;8(2).

128. Rango T, Vengosh A, Jeuland M, Tekle-Haimanot R, Weinthal E, Kravchenko J, et al. Fluoride exposure from groundwater as reflected by urinary fluoride and children's dental fluorosis in the Main Ethiopian Rift Valley. Sci Total Environ. 2014;496:188–97.

129. Rango T, Kravchenko J, Atlaw B, McCornick PG, Jeuland M, Merola B, et al. Groundwater quality and its health impact: An assessment of dental fluorosis in rural inhabitants of the Main Ethiopian Rift. Environ Int. 2012 Aug;43(1):37–47.

130. Tarekgne EK, Skjerdal T, Skeie S, Rudi K, Porcellato D, Félix B, et al. Enterotoxin gene profile and molecular characterization of staphylococcus aureus isolates from bovine bulk milk and milk products of Tigray Region, Northern Ethiopia. J Food Prot. 2016 Aug 1;79(8):1387–95.

131. Ababu A, Endashaw D, Fesseha H. Isolation and antimicrobial susceptibility profile of Escherichia coli O157: H7 from raw milk of dairy cattle in Holeta District, central Ethiopia. Int J Microbiol. 2020;2020.

132. Welearegay H, Yilma Z, Tekle-Giorgis Y. Hygienic practices and microbiological quality of raw milk produced under different farm size in Hawassa, southern Ethiopia. Agric Res Rev. 2012;1(4):132–42.

133. Hiko A, Bushura E, Belina D. Occurrence of Listeria in food chilling facilities of the different campuses in Haramaya University, Ethiopia. Sci Afr. 2019;3:e00074.

134. Kassa A, Zewude G, Tessema TS. Investigation on Bacillus cereus and associated risk factors in bovine raw milk in Debre Zeit town, Ethiopia. Rev Med Veterinaire. 2017;168(10–12):213–8.

135. Garedew L, Berhanu A, Mengesha D, Tsegay G. Identification of gram-negative bacteria from critical control points of raw and pasteurized cow milk consumed at Gondar town and its suburbs, Ethiopia. BMC Public Health. 2012;12(1):1.

136. Megersa R, Mathewos M, Fesseha H. Isolation and Identification of Escherichia coli from Dairy Cow Raw Milk in Archives of Veterinary and Animal Sciences Isolation and Identification of Escherichia coli from Dairy Cow Raw Milk in Bishoftu Town , Central Ethiopia. 2020;1(1):1–8.

137. Asfaw Geresu M, Regassa S. Escherichia coli O157: H7 from Food of Animal Origin in Arsi: Occurrence at Catering Establishments and Antimicrobial Susceptibility Profile. Sci World J. 2021;2021.

138. Asfaw Geresu M, Assefa Wayuo B, Mamo Kassa G. Occurrence and antimicrobial susceptibility profile of salmonella isolates from animal origin food items in selected areas of Arsi zone, southeastern Ethiopia, 2018/19. Int J Microbiol. 2021;2021.

139. Guesh M. Prevalence and antimicrobial susceptibility of Salmonella species from lactating cows in dairy farm of Bahir Dar Town, Ethiopia. Afr J Microbiol Res. 2017;11(43):1578–85.

140. Reta MA, Bereda TW, Alemu AN. Bacterial contaminations of raw cow's milk consumed at Jigjiga city of Somali regional state, Eastern Ethiopia. Int J Food Contam. 2016;3(1).

141. Sani M, Gugsa G, Mekuria A, Ahmed M. Identification and Antimicrobial Resistance Pattern of Staphylococcus aureus Isolated from Bovine Raw Milk in Addis Ababa, Ethiopia. Abyss J Sci Technol. 2018;3(1):20–7.

142. Seifu E and FB. Microbiological quality of goat milk in Awassa, Ethiopia. 2006;

143. Regasa S, Mengistu S, Abraha A. Milk Safety Assessment, Isolation, and Antimicrobial Susceptibility Profile of Staphylococcus aureus in Selected Dairy Farms of Mukaturi and Sululta Town, Oromia Region, Ethiopia. Vet Med Int. 2019;

144. Sileshi S, Munees A. Prevalence and antibiotic susceptibility of Staphylococcus aureus from lactating cows milk in Bahir Dar dairy farms. Afr J Microbiol Res. 2016;10(35):1444–54.

145. Weldeabezgi LT, Atsbha TW, Kassegn HH, Gebremichael TF, Berhe MH. A quantitative risk assessment model for Staphylococcus aureus and Salmonella associated with consumption of informally marketed milk products in Tigray, Ethiopia. J Food Saf. 2020;40(2).

146. Tessema D, Tsegaye S. Study on the Prevalence and Distribution of Staphylococcus aureus in Raw Cow Milk Originated from Alage Atvet College Dairy Farm, Ethiopia. J Nutr Food Sci. 2017;07(02).

147. Ayele Y, Gutema FD, Edao BM, Girma R, Tufa TB, Beyene TJ, et al. Assessment of Staphylococcus aureus along milk value chain and its public health importance in Sebeta, central Oromia, Ethiopia. BMC Microbiol. 2017;17(1):1–7.

148. Ebissa T, Aki A. Bacteriological quality assesement of raw cow's milk in and around Asossa, Ethiopia. ResearchgateNet. 2017;(October 2020).

149. Fesseha, H; Aliye, S; Kifle, T; Mathewos M. Isolation and Multiple Drug Resistance Patterns of Salmonella Isolates from Selected Dairy Farms in Hawassa Town, Ethiopia. J Vet Sci Med. 2020;8(1):1–7.

150. Habtamu K, Ajebu N, Edessa N. Microbiological quality and safety of milk production and marketing in Hawassa district, Ethiopia. Afr J Microbiol Res. 2018;12(25):587–94.

151. Liyuwork T, Biruhalem T, Sefinew A, Haile A, Zufan S, Haileleul N. Prevalence and antimicrobial resistance profile of Salmonella isolates from dairy products in Addis Ababa, Ethiopia. Afr J Microbiol Res. 2013;7(43):5046–50.

152. Befekadu T, Genene T, Bizuayehu B, Abebe M. Prevalence and antimicrobial susceptibility pattern of Staphylococcus aureus from raw camel and goat milk from somali region of Ethiopia. Afr J Microbiol Res. 2016;10(28):1066–71.

153. Tafere G. A review on Traditional Fermented Beverages of Ethiopian. J Nat Sci Res Www. 2015;5(15):2225–921.

154. Gemechu AT. Assessment of Safety and Quality of Raw Whole Cow Milk Produced and Marketed by Smallholders in Central Highlands of Ethiopia. CoreAcUk. 2016;49(2007):63–71.

155. Abraha A, Bikila T, Alemu S, Muktar Y. Bacillus cereus isolation and load from raw cow milk sold in markets of Haramaya district, eastern Ethiopia. Int J Food Contam. 2017;4(1):4–9.

156. Adam, Birhanu; Hailu M. Microbiological Quality of Raw Cow's Milk In and Around Bahir Dar City, Ethiopia. Food Sci Qual Manag. 2019;(July).

157. Deresse Daka,. Antibiotic-resistance Staphylococcus aureus isolated from cow's milk in Hawassa area, South Ethiopia. Afr J Microbiol Res. 2012;6(27):1–6.

158. Berhe G, Wasihun AG, Kassaye E, Gebreselasie K. Milk-borne bacterial health hazards in milk produced for commercial purpose in Tigray, northern Ethiopia. BMC Public Health. 2020;20(1):1–8.

159. Abunna F, Ashenafi D, Beyene T, Ayana D, Mamo B, Duguma R. Isolation, identification and antimicrobial susceptibility profiles of *Salmonella* isolates from dairy farms in and around Modjo town, Ethiopia. Ethiop Vet J [Internet]. 2017 Sep 11 [cited 2021 Nov 26];21(2):92. Available from: https://www.ajol.info/index.php/evj/article/view/160910

160. Wasie A, Pal M, Zeru F. A Study on Assessment of Microbial Quality of Raw Camel Milk in Dubti, Ethiopia. Haryana Vet. 2015;54(2):184–7.

161. Berhanu M, Adal M, Sahile S. Microbial Quality Spectrum of Packed and Fresh Fruit Juices in Gondar Town Supermarkets and Cafes, Northwestern Ethiopia. J Microbiol Res. 2020;10(2):45–54.

162. Chaithanya KK, Kebede H. Public health risks and bacterial safety of fruit juices prepared in Axum town, north Ethiopia Medium Scale project View project Student Project View project. J Pharm Res. 2018;12(July).

163. Kechero FK, Baye K, Tefera AT, Tessema TS. Bacteriological quality of commonly consumed fruit juices and vegetable salads sold in some fruit juice houses in Addis Ababa, Ethiopia. J Food Saf. 2019;39(1):1–9.

164. Leul A, Kibret M. Bacteriological Safety of Freshly Squeezed Mango and Pineapple Juices Served in Juice Houses of Bahir Dar Town, Northwest Ethiopia. Int J Sci Basic Appl Res. :24–35.

165. Senbeta D, Beyene M. Bacteriological Assessment of Avocado Juice Vended in Cafeteria And Restaurants in Adigrat Town , Northern Ethiopia. Int J Adv Technol Innov Res. 2017;09(04):593–6.

166. Tafere G, Desaleegn A. Microbial load and safety of locally prepared fresh fruit juices in cafeteria and restaurants in Mekelle city, Northern Ethiopia. Indian J Tradit Knowl. 2017;16(4):598–604.

167. Tsige K, Resturants C, Town J. Microbiological Safety of Fruit Juices Served in Cafes/Resturants, Jimma Town, Southwest Ethiopia. Ethiop J Health Sci. 2008;18(3).

168. Degaga B, Girma G, Woyessa D, Bacha K. Microbiological quality and safety of weaning foods of in-patient infants in Jimma University Specialized Hospital, Jimma Town, Southwest Ethiopia. J Biol Chem Res. 2015;32(2):673–82.

169. Haftay A, Geberemedhin H, Belay A, Goytom E, Kidane W. Antimicrobial resistance profile of Staphylococcus aureus isolated from raw cow milk and fresh fruit juice in Mekelle, Tigray, Ethiopia. J Vet Med Anim Health. 2018;10(4):106–13.

170. Assefa E, Beyene F, Santhanam A. Isolation and characterization of inhibitory substance producing lactic acid bacteria from Ergo, Ethiopian traditional fermented milk. 2008;12.

171. Abebe B, Mitiku E, Zelalem Y. Microbial properties of Ethiopian dairy products: A review. Afr J Microbiol Res [Internet]. 2014 Jun 4 [cited 2021 Nov 26];8(23):2264–71. Available from: http://academicjournals.org/journal/AJMR/article-abstract/4363D9D45166

7. APPENDICES

7.1. APPENDIX 1: BEVERAGE SYSTEMATIC LITERATURE REVIEW PROTOCOL

ASPECT	DESCRIPTION
Rationale	This is a study on occurrence of hazards in beverages in Ethiopia. It aims to i) identify the priority hazards; ii) attribute these to their specific sources (or value chains of relevance considering all ingredients), and iii) use the findings to inform the choice of interventions.
Aim	To identify biological and chemical hazards associated with beverage consumption in Ethiopia (according to prevalence within beverages and incidence and health burden in humans).
Research question	What hazards (biological/chemical) have been identified in beverages consumed in Ethiopia?
	What is the prevalence (% of contaminated products) and concentration of hazards in beverages consumed in Ethiopia?
	What is the spatial distribution of studies reporting these hazards (i.e. where, within the country, were the studies conducted)?
Population	All beverages consumed in Ethiopia
Intervention	N/A
Control	N/A
Outcome	Map of beverage-associated hazards reported in Ethiopia.
	Prevalence (% of contaminated products) and Concentration of hazards
Setting	Ethiopia
Protocol registration	N/A
Eligibility criteria	Inclusion criteria • Type of studies: observational studies, secondary data analysis, (literature) reviews • Time limits: Studies published from 2000 to 2021. • Language – English (mainly)
	Exclusion criteria • Studies not considering biological or chemical hazards associated with beverages. • Studies on water quality/safety not associated with drinking water. • If the population is outside Ethiopia • Experimental laboratory studies • Studies that exclusively focus on non-beverage associated illness/hazards. • Antimicrobial resistance studies (including antimicrobial residues) Studies not reporting information on beverage-associated hazard presence, prevalence, incidence or health burden (i.e., studies looking at prevalence of hazards at primary production on targets that are not food per se: i.e., faeces from animals, serology from animals, or carriage in vectors)
Information sources	Three online databases: PubMed and ScienceDirect (primary); Google Scholar (complementary).
Search	A study summary table with search findings

Study selection	Observational studies, secondary data analysis, (literature) reviews
Data collection process	TITLE/ABSTRACT • Download of titles/abstracts and removal of duplicates. • Independent double screening of title/abstract (inclusion/exclusion criteria) by Reviewers #1 and #2). Screening will be done using the Rayyan QCRI software. The tool also allows for identification and removal of duplicates. • Discussion to reach agreement by Reviewers #1 and #2 or review of articles considered relevant by only Reviewer #3 • Selection of articles considered relevant by at least two of the reviewers. • Reviewers #3 and #4 will monitor the whole review process on Rayyan.
	FULL PUBLICATIONS • Download of full publications by Reviewers #1 and #2 • Full paper double review (inclusion/exclusion criteria) by Reviewers #1 and #2 using the Rayyan QCRI software. • 5% of included and excluded publications will be reviewed by Reviewers #3 and #4 • Any discordance in classification to be reviewed by Reviewers #3 and #4 • Full paper single review (quality criteria) by Reviewers #1 and #2.
	DATA EXTRACTION • Reviewers #1 and #2 overseen by #3 and #4 • Standardized data extraction file • Pretesting of template by both Reviewers (5-10% of the publications) and comparing data extracted • Single data extraction and combining data into one database. • Validation of the data entered by Reviewers #1 and #2 (review entries for 10-15% of randomly selected papers).
Assessment of bias	Follow Cochrane Assessment of Bias

7.2. APPENDIX 2: SUMMARY OF ARTICLES INCLUDED IN THIS REVIEW

REF.	LOCATION	PRODUCT	HAZARD		SAMPLING POINT
			TYPE	NAME	
FOOD REVIEW					
BOVINE DAIRY PRODUCTS					
(11)	SNNPR	Cottage cheese	Biological	*B. cereus; S. aureus;* Mesophilic aerobic bacteria; Yeasts; *Enterococci*	Market
(12)	Amhara	Ice cream	Biological	Multiple	Farm, retail
(13)	Oromia	Cottage cheese	Biological	*Listeria*	Retail, market
(14)	Oromia	Cottage cheese	Biological	*Listeria*	Supermarket, retail
(15)	Oromia	Yogurt	Biological	*Listeria*	Farm
(16)	Amhara	Cottage cheese	Biological	*Salmonella*	Cafeteria/, retail
(17)	Amhara	Raw milk	Biological	*Mycobacterium bovis* and *tuberculosis*; Atypical mycobacteria*	Cattle farmers
(18)	Oromia	Raw milk	Biological	*Mycobacterium bovis* and *Tuberculosis**	Household
(19)	Oromia	Raw milk	Biological	*Mycobacterium bovis* and *Tuberculosis**	Farm
** Included as suspect human pathogen.*					
BEEF					
(26)	SNNPR [14]	Raw beef	Biological	*Salmonella*	Abattoir
(29)	Oromia	Raw beef	Biological	*E. coli* O157: H7	Abattoir, retail
(33)	Oromia	Beef carcass	Biological	*E. coli* O157: H7	Processing plant, retail
(30)	Oromia	Raw beef	Biological	*E. coli; E. coli* O157H7	Abattoir, retail
(98)	Oromia	Beef Carcass	Biological	Coagulase-negative staph.	Abattoir
(23)	Oromia	Raw beef	Biological	*Salmonella, Listeria*	Abattoir, butcher, restaurants
(25)	SNNPR	Beef carcass and raw beef	Biological	*Salmonella*	Slaughterhouse, butcher shops

[14] SNNPR = Southern Nations, Nationalities, and People's Region (Ethiopia)

(35)	Amhara	Raw beef	Biological	*Staphylococcus aureus*	Butcher shops
(21)	Amhara	Raw beef	Biological	Aerobic mesophilic count; Total coliform count; *S. aureus* count; *Salmonella*	Retail
(22)	Oromia	Beef carcass and raw beef	Biological	*E. coli; S. aureus; Salmonella;* Klebsiella Proteus	Abattoir, butcher shops
(32)	Oromia	Beef carcass and minced meat	Biological	*E. coli O157: H7*	Retail, restaurants
(24)	SNNPR	Beef carcass	Biological	*Salmonella*	Abattoir, retail
(31)	Oromia	Beef carcass and raw beef	Biological	*E. coli O157: H7*	Abattoir, retail
(7)	Oromia	Beef carcass	Biological	Staphylococcus	Abattoir
EGGS					
(16)	Amhara	Eggs	Biological	*Salmonella*	Butcher shop, cafeteria, retail
(37)	Oromia	Eggs	Biological	*S. enteritidis*	Market
(38)	Oromia	Egg sandwich	Biological	*Salmonella, Shigella*	Retail
(39)	Oromia	Egg	Biological	*Salmonella*	Market
FRUITS AND VEGETABLES					
(40)	SNNPR	Lettuce, cabbage Carrot, tomato, green pepper	Biological	Ascaris lumbricoides; *Toxocara* spp; Hymenolepis nana; Entamoeba histolytica/dispar; H. diminuta; Cystoisospora belli; Giardia intestinalis; Cryptosporidium; *Cyclospora* spp	Market
(42)	Oromia	Lettuce, green pepper	Biological	*Salmonella; Shigella; Staphylococci, Enterobacteriacea*	Supermarket
(44)	Tigray	Pepper, lettuce, cabbage, guava	Biological	Cryptosporidium oocysts; Giardia cysts	Farm
(41)	Amhara	Cabbage, lettuce, carrots, spinach	Biological	*Strongyloides* spp; Entamoeba histolytica/E. disparcy cysts; *G. lamblia; Cryptosporidium* spp	Market
(43)	Oromia	Lettuce	Biological	*E. coli O157: H7*	Retail

(99)	SNNPR	Tomato, lettuce, carrot, cabbage, green pepper	Biological	Ascaris lumbricoides; Toxocara spp; Hymenolepis nana; Entamoeba histolytica/dispar; Giardia intestinalis; H. diminuta; Cystoisospora; *Toxocara* spp; Cystoisospora belli; Giardia intestinalis	Market
GRAINS, NUTS, AND SEEDS					
(45)	Amhara	Barley, sorghum, wheat, teff	Chemical	Aflatoxin B(1) (AFB1); Ochratoxin A (OTA); Deoxynivalenol (DON); Nivalenol (NIV); Zearalenone (ZEN)	Threshing yards, traditional storage structures
(46)	Oromia	Groundnut	Biological and Chemical	*Aspergillus*; Aflatoxin	Farmers' stores
(47)	South Ethiopia	Maize grain	Biological and Chemical	Aspergillus; Fusarium; Penicillium; Zearalenone; Zearalenone sulfate; Fumonisin B1-B4; Aflatoxin B1	Farm
(48)	SNNPR	Corn; rice; millet; sorghum	Chemical	p,p′-DDT and DDE; chlordane; hexachlorbenzene; β-lindane; lindane; α-lindane; aldrin; hexachlorepoxide; α-endosulfan; β-endosulfan; endosulfan sulfate; methoxychlor; heptachlor; dimethoate; chlorpyrifos, profenofos	Farm

REF.	LCOATION	PRODUCT	HAZARD		SAMPLING POINT
			TYPE	NAME	
BEVERAGE REVIEW					
WATER					
(100)	SNNPR	Water	Biological	Multiple	Source
(101)	Oromia	Water	Biological	Multiple	Source
(83)	Amhara	Water	Biological	*E. coli*	Source
(102)	Oromia	Water	Chemical	Lead	Source
(103)	Oromia	Water	Biological	Multiple	Source

(104)	Amhara	Water	Biological	Multiple	Household
(105)	Oromia	Water	Chemical	Lead	Source
(106)	Tigray	Water	Chemical	Multiple	Source
(89)	Addis Ababa	Water	Chemical	Multiple	Household
(74)	Somali region	Water	Biological	Multiple	Household
(91)	Addis Ababa	Water	Chemical	Multiple	Source
(75)	Amhara	Water	Biological	Multiple	Source
(107)	Oromia	Water	Chemical	Multiple	Source
(108)	Oromia	Water	Biological	Multipole	Source
(109)	Amhara	Water	Biological	*Entero-bacteriaceae*	Household
(110)	SNNPR	Water	Biological	*E. coli*	Source
(111)	Tigray	Water	Chemical	Lead	Source
(112)	Oromia	Water	Chemical	Lead	Source
(113)	Addis Ababa	Water	Biological	*E. coli*	Source
(114)	Addis Ababa	Water	Biological	*E. coli*	Hotels
(82)	Amhara	Water	Biological	Multiple	Source
(88)	Tigray	Water	Chemical	Multiple	Source
(115)	SNNPR	Water	Chemical	Multiple	Source
(73)	Oromia	Water	Biological, Chemical	Multiple	Household, source
(80)	Oromia	Water	Biological	*E. coli*	Household, source
(116)	SNNPR	Water	Biological	*E. coli*	Household, source
(117)	Tigray	Water	Chemical	Multiple	Source
(118)	Oromia	Water	Chemical	Lead	Source
(119)	Addis Ababa	Water	Chemical	Fluoride	Source
(120)	Addis Ababa	Water	Chemical	Arsenic	Source
(121)	Addis Ababa	Water	Chemical	Multiple	Source
(87)	Addis Ababa	Water	Chemical	Multiple	Source
(122)	Oromia	Water	Chemical	Multiple	Source
(123)	Oromia	Water	Biological	Multiple	Source
(124)	Oromia	Water	Chemical	Lead	Source
(125)	Oromia	Water	Biological, Chemical	Multiple	Source
(126)	Amhara	Water	Chemical	Lead	Source

(127)	Addis Ababa	Water	Biological	*E. coli*	Source
(128)	Gambela	Water	Chemical	Fluoride	Source
(76)	Tigray	Water	Biological	Multiple	Source
(129)	Addis Ababa	Water	Chemical	Fluoride	Source
BOVINE DAIRY PRODUCTS (COW MILK)					
(130)	Tigray	Fermented milk	Biological	Multiple	Farm
(8)	Oromia	Raw milk	Biological	*Staph. aureus*	Farm
(9)	Sidama	Raw milk	Biological	*Staph. aureus*	Farm
(10)	Oromia	Raw milk	Biological	*Salmonella*	Farm
(12)	Amhara	Raw milk	Biological	Multiple	Farm, retail
(59)	Amhara	Raw and Pasteurized Milk	Biological	Multiple	Farm, retail
(52)	Amhara	Milk	Chemical	Multiple	Farm
(131)	Oromia	Milk	Biological	*E. coli*	Farm
(132)	Sidama	Milk	Biological	Yeast and Mold	Farm, shops
(133)	Oromia	Milk	Biological	*Listeria*	Cafeteria
(134)	Amhara	Milk	Biological	*Bacillus cereus*	Farm
(135)	Amhara	Milk	Biological	Multiple	Farm, supermarket
(16)	Amhara	Milk	Biological	*Salmonella*	Cafeteria, retail
(136)	Oromia	Milk	Biological	*E. coli*	Farm
(53)	Tigray	Milk	Biological	Multiple	Farm
(137)	Oromia	Milk	Biological	*E. coli*	Cafeteria, retail
(138)	Oromia	Milk	Biological	*Salmonella*	Cafeteria, retail
(139)	Amhara	Milk	Biological	*Salmonella*	Farm
(52)	Tigray	Milk	Biological	*Camplyobacter*	Farm
(54)	Benishagul-ghumuz	Milk	Biological	*E. coli*	Farm, retail
(140)	Somali	Milk	Biological	Multiple	Farm, retail
(86)	Oromia	Milk	Chemical	Dichlorodiphenyl-trichloroethane	Farm
(141)	Addis Ababa	Milk	Biological	*Staph. aureus*	Farm
(142)	Sidama	Milk	Biological	Multiple	Farm
(143)	Oromia	Milk	Biological	*Staph. aureus*	Farm
(144)	Amhara	Milk	Biological	*Staph. aureus*	Farm
(58)	Tigray	Milk	Biological	Multiple	Farm, retail
(13)	Addis Ababa	Milk	Biological	*Listeria*	Retail, market

(7)	Addis Ababa	Milk	Biological	*Staph.*	Farm
(145)	Tigray	Milk	Biological	Multiple	Farm, retail
(146)	Oromia	Milk	Biological	*Staph. aureus*	Farm
(55)	Addis Ababa	Milk	Biological	Multiple	Household, street vendor
(10)	Addis Ababa	Milk	Biological	*Salmonella*	Farm
(147)	Oromia	Milk	Biological	*Staph. aureus*	Farm, retail
(148)	Benishagul-ghumuz	Milk	Biological	Multiple	Household, farm, retail
(149)	Sidama	Milk	Biological	*Salmonella*	Farm
(98)	Amhara	Milk	Biological	*Staph.*	Farm
(84)	Oromia	Milk	Chemical	Aflatoxin M1 & M2	Farm, retail
(80)	Oromia	Milk	Biological	*E. coli*	Household
(150)	Sidama	Milk	Biological	Multiple	Household, farm, retail
(151)	Addis Ababa	Milk	Biological	*Salmonella*	Supermarket
(152)	Somali region	Milk	Biological	*Staph. aureus*	Household
(85)	Addis Ababa	Milk	Chemical	Antimicrobials	Farm
(153)	Addis Ababa	Milk	Biological	*Salmonella*	Cafeteria
(154)	Addis Ababa	Milk	Biological	*Enterobacteriaceae*	Farm
(155)	Oromia	Milk	Biological	*Bacillus*	Market
(156)	Amhara	Milk	Biological	Multiple	Farm, retail
(56)	Amhara	Milk	Biological	Multiple	Farm, retail
(157)	Sidama	Milk	Biological	*Staph. aureus*	Farm
(8)	Addis Ababa	Milk	Biological	*Staph. aureus*	Farm
(158)	Tigray	Milk	Biological	Multiple	Farm, retail
(159)	Addis Ababa	Milk	Biological	*Salmonella*	Farm
BOVINE DAIRY PRODUCTS (YOGURT)					
(60)	Amhara	Milk, Yogurt	Biological	*Staph. aureus*	Farm, retail
(61)	Oromia	Milk, Yogurt	Biological	Aflatoxin AFM1	Farm, retail
(62)	Tigray	Milk, Yogurt	Biological	*Staph. aureus*	Farm cafeteria
(63)	Oromia	Yogurt	Biological	*Staph. aureus,* other *Staphylococcus*	Cafeteria
(15)	Addis Ababa	Yogurt	Biological	*Listeria*	Farm
(64)	Addis Ababa	Milk, Yogurt	Biological	*Staph. aureus,* Coagulase-negative	Farm

				Staphylococcus	
(65)	Oromia	Milk, Yogurt	Biological	*Listeria* incl. *L. monocytogenes*	Supermarket, cafeteria
(66)	Amhara	Milk, Yogurt	Biological	Multiple including *E. coli*, *E.coli* O157:H7, *S. aureus*	Household, market
(67)	Amhara	Ergo [d]	Biological	Multiple incl. *Staphylococcus*	Household
(68)	Amhara	Ergo [d], Arrera [e]	Biological	Multiple	Retail
(69)	Sidama	Ergo [d]	Biological	*Staphylococcus*	Farm
(70)	Addis Ababa	Ergo [d]	Biological	Multiple (coliforms, Enterobacteriaceae)	Farm, retail
CAMEL MILK					
(71)	Somali	Camel Milk	Biological	Multiple	Household, retail
(72)	Somali	Camel Milk	Biological	Multiple	Farm, market
(160)	Afar	Camel Milk	Biological	Multiple	Farm, market
FRESH / PACKED JUICE					
(161)	Amhara	Fresh / Packed Juice	Biological	Multiple	Supermarket
(79)	Amhara	Fresh / Packed Juice	Biological	Multiple	Cafeteria
(162)	Tigray	Fresh / Packed Juice	Biological	Multiple	Cafeteria
(78)	Tigray	Fresh / Packed Juice	Biological	Multiple	Juice house
(163)	Addis Ababa	Fresh / Packed Juice	Biological	Multiple	Juice house
(164)	Amhara	Fresh / Packed Juice	Biological	Multiple	Juice house
(165)	Tigray	Fresh / Packed Juice	Biological	Multiple	Cafeteria
(166)	Tigray	Fresh / Packed Juice	Biological	Multiple	Cafeteria
(167)	Oromia	Fresh / Packed Juice	Biological	Multiple	Cafeteria
MULTIPLE PRODUCTS					

(168)	Oromia	Milk, Fresh and Packed Juice	Biological	Multiple	Source
(57)	Tigray		Biological	*E. coli*	Farm, Juice house
(169)	Tigray		Biological	Multiple	Farm, Juice house
(92)	Dire Dawa	Water, Fresh and Packed Juice	Biological	Multiple	Hotel, supermarket, street vendor

Notes

[d] "Ergo" is a traditional fermented milk product, made by fermenting milk under ambient temperature with no starter cultures to initiate the fermentation processes added (170).

[e] "Arrera" is a by-product of Ergo obtained after removal of the milk fat, kibe, following churning. It has a similar color to ergo, but with a slightly smoother appearance and a thinner consistency, although thicker than fresh milk and basically, contains the casein portion of milk (171).