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Foodborne disease hazards and burden in Ethiopia: A systematic literature review, 1990–2019

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Background: Foodborne disease (FBD) affects millions of people each year, posing a health burden similar to malaria, tuberculosis or HIV. A recent World Bank study estimated the productivity losses alone attributed to unsafe food within Africa at $20 billion in 2016, and the cost of treating these illnesses at an additional $3.5 billion. Ethiopia faces multiple food safety challenges due to lack of infrastructure and basic pre-requisites for food safety such as clean water and environment, washing facilities, compounded by limited implementation of food safety regulations, and a lack of incentives for producers to improve food safety. A consolidation of our understanding and evidence of the source, nature and scale of FBD in Ethiopia is needed to inform policy and future research. We performed a Systematic Literature Review (SLR) of publications on FBD occurrence in Ethiopia including hazard presence and impact.

Method: The SLR followed Cochrane and PRISMA guidelines. We searched PubMed and CAB-Direct for relevant publications between 1990 and 2019 (inclusive). Observational studies and reviews were included. Two reviewers screened titles and abstracts, and retained publications were reviewed in full for quality and data extraction.

Result: In total 128 articles met the inclusion criteria. Most articles focused on the identification of biological hazards in food. High levels of microbial contamination in different food value chains were often found in the small, *ad hoc,* observational studies that dominated the literature. Raw milk (22/128, 17.0%) and raw beef (21/128, 16.4%) were the most studied food products. Foodborne (FB) parasites were often found at higher rates in food than bacterial and viral pathogens, possibly due to differences in ease of identification. High levels of bacterial contamination on the hands of food handlers were widely reported. There were no reports on the incidence of human FBDs or resulting health and economic impacts.

Conclusion: Our findings reflect existing concerns around food safety in Ethiopia. A lack of substantial, coordinated studies with robust methodologies means fundamental gaps remain in our knowledge of FBD in Ethiopia, particularly regarding FBD burden and impact. Greater investment in food safety is needed, with enhanced and coordinated research and interventions.

KEYWORDS

food borne diseases, value chains, hazards, burden, Ethiopia

1. Introduction

Foodborne diseases (FBDs) are illnesses caused by contaminated, or naturally harmful, food. A foodborne (FB) hazard is anything present in food that can harm consumers' health. They are usually categorized as: biological hazards, which are pathogenic organisms and the toxins they produce; chemical hazards, which may be artificial or natural; and physical hazards, such as foreign objects in food (Grace et al., 2018). The most comprehensive estimates of the health burden of FBDs in African countries are those provided by the World Health Organization (WHO) Foodborne Disease Epidemiology Reference Group (FERG) (Havelaar et al., 2015), which estimated that FBD burden is comparable to that of malaria, HIV/AIDS or tuberculosis. Nearly all of this burden (98%) is borne by low-income countries and most of it (97%) is due to biological hazards (Havelaar et al., 2015), with diarrheal disease agents being the most important contributor to overall FBD burden in African region E (which includes Ethiopia), followed by helminths and invasive bacteria (Havelaar et al., 2015).

Accurate information on the health and burden associated with FBDs is critical for countries to guide food safety risk management strategies and to justify allocation of resources. The lack of reliable data from surveillance systems for FBD in low and middle income countries limits the ability to conduct risk-based food safety management. FBD burden is thought to be high in Ethiopia (Pieracci et al., 2016; Keba et al., 2020; Belina et al., 2021; Mekonnen et al., 2021). *Salmonella*, *Listeria monocytogenes*, *Escherichia coli (E. coli)*, *Campylobacter* spp. and *Shigella* are among the most common FB pathogens reported from Ethiopia and food-producing animals are the major reservoirs (Belina et al., 2021). Reports of food poisoning outbreaks in Ethiopia are often linked to consumption of raw meat and milk (Kassahun and Wongiel, 2019), However, cases of FB illnesses are underreported and are rarely investigated in detail (Ayana et al., 2015).

Given the lack of knowledge around this vital topic, this Systematic Literature Review (SLR) was conducted to investigate the existing literature and collate the evidence on FB hazards in Ethiopia. The SLR did not look at specific pre-specified hazards or specific foods, but instead explored available literature on any FB hazards and any foods. This SLR is one early output of a portfolio of research projects[1] looking to improve understanding and control of FBD in Ethiopia. This review was used to inform these projects which then went on to examine FBD using various approaches, including modeling, molecular and field-based approaches.

2. Methods

2.1. Research question

This SLR aimed to inform the design of further studies by addressing the following research questions:

- What biological and chemical hazards have been identified in foods in Ethiopia?
- What is the prevalence (i.e., percent of contaminated products) and concentration of these hazards in foods in Ethiopia?
- What is the incidence of FBD and what is the associated health burden in Ethiopia?

2.2. Search strategy

We conducted an SLR following the methods suggested by the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). A comprehensive search on PubMed and CAB Direct was performed for articles published in English from the 1st of January of 1990 to the 30th of September 2019, inclusive. The search was done on 30th of September 2019. The search syntax with different search terms and Boolean Operators including the following search terms:

i foodborne OR "food borne" OR food-borne OR "food safety" OR "food related" OR "food associated" OR "food derived" OR "food* illness" OR "food* disease*" OR "food* intoxica*" OR "food pathogen" OR "food* poison*" OR "food* microb*" OR "food* vir*" OR "food parasit*" OR "food* toxin."

ii AND Ethiop*.

The syntax was left broad and generic to capture all the literature covering the various aspects of interest (e.g., prevalence, impact, risk factors, and control). Inclusion and exclusion criteria are shown in Table 1.

2.3. Article selection process and quality assessment

Lists with the identified titles and abstracts were downloaded to an excel file and checked for duplicates using Mendeley (https://www.mendeley.com/download-reference-manager/windows). After the removal of duplicates, titles and abstracts were reviewed independently by two reviewers against the inclusion and exclusion criteria. All titles considered relevant by both reviewers were included; articles considered relevant by just one reviewer were reviewed by a third reviewer who made a final decision on article inclusion.

Full articles for the included titles were obtained, when available. The full articles were then subjected to a two-step review process; Articles were reviewed against (1) inclusion/exclusion criteria (as

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- Urban food markets in Africa: Incentivizing food safety using a pull-push approach ("pull-push" project), led by the International Livestock Research Institute.
- The assessment and management of risk from non-typhoidal Salmonella, diarrheagenic *Escherichia coli* and *Campylobacter* in raw beef and dairy in Ethiopia (TARTARE), led by Ohio State University.
- Foodborne disease epidemiology, surveillance and control in African LMIC (FOCAL), led by Technical University of Denmark.
- Ensuring the safety and quality of milk and dairy products across the dairy value chain in Ethiopia (ENSURE), led by Addis Ababa University.

above) and (2) quality criteria. The quality criteria considered the paper's merit on five aspects: (1) selection of subjects, (2) study methods, (3) data analysis, (4) reporting of methods and results, and (5) reliability of results (Table 2). Quality of the papers was rated as "Good" (scoring positively to all five quality criteria), "Moderate" (scoring positively in three or four of the quality criteria) or "Poor" (scoring positively in two or less of the quality criteria). However, an overall reviewer's overall impression could over-ride this rating. Poor-quality articles were excluded from data synthesis.

2.4. Data extraction and analysis

An excel template was designed to allow standardized data extraction by different reviewers (Supplementary material). Ten percent ($n = 13$) of the full articles were systematically selected by dividing the total number of included articles by 13 so each 10th article in the list was selected. Then theses were reviewed in parallel by two reviewers and outputs were compared to ensure the review process was standardized and comparable across reviewers. After standardization, the remaining articles were reviewed by a single reviewer. Given the large diversity of foods, organisms, and studies, it was not possible to conduct any meaningful meta-analysis.

TABLE 1 Inclusion and exclusion criteria (inclusion also require Ethiopia focus and published on or after 1st January 1990 but not after 30th September 2019).

Criteria	Included articles	Excluded articles
Study design	Observational studies (cross-sectional, case-control or cohort studies), reviews, randomized control trials (RCT) and experimental studies	Laboratory based/experimental studies
Study focus	FBDs incidence, health burden, prevalence in food products	Non-foodborne illness/hazards, non-food samples (i.e., feces from animals, serology, or carriage in vectors), antimicrobial resistance studies; and studies on aspects of basic science (i.e., immunology/gene sequencing/chemistry)

3. Results

3.1. Literature search

The database searches returned 760 and 244 records from PubMed and Cab Direct, respectively. Out of 519 unique articles, 307 were excluded at title and abstract review, and 3 were not available as full manuscripts (Figure 1). From the remaining 209 full articles, 53 were excluded based on the inclusion/exclusion criteria and 28 based on the quality criteria. These were excluded due to poor scientific quality, mostly from biased selection of subjects, inappropriate data analysis and incomplete and/or inaccurate results.

Data was ultimately extracted from 128 selected articles.

3.2. Profile of the reviewed publications

Articles reported studies conducted in Oromia (42/128, 32.8%), Amhara (30/128, 23.4%), Addis Ababa (29/128, 22.6%), and Southern Nation Nationalities People (SNNP; 21/128, 16.4%) region. Few studies had been done in the other regions of the country. These were generally conducted in major cities and were not representative of all regional states (Figure 2).

Most articles were conducted in the capital city, Addis Ababa ($n = 29$), followed by Debre Zeit ($n = 14$), Awassa ($n = 9$), Jimma ($n = 9$), Gondar ($n = 9$), Bahir Dar ($n = 7$), Haromaya ($n = 6$), and Arba Minch ($n = 5$) the location of well-established universities.

The number of articles relevant to the topic identified in our review increased over time (Figure 3).

Majority of the articles included in the review (119/128, 93%) focused on biological hazards and six articles looked at presence of chemical hazards in food. Among the 119 articles focused on biological hazards, 82/119 (68.9%) investigated presence of pathogens in food, 48/119 (40.3%) presence in human samples (stool and hand swab samples) and 19/119 (15.9%) in food environments (i.e., beef slaughterhouses, butcheries, and milk shops). While half of the articles studied one food item and one hazard, other half covered various hazards and/or various matrices. None of the selected studies covered incidence of FBD or FBD burden.

The majority ($n = 119$, 92.9%) of the 128 papers examined the presence of bacteria ($n = 87$, 73.11%), parasites ($n = 23$, 19.33%), parasites and bacteria ($n = 7$, 5.88%), fungal toxins ($n = 3$, 2.52%), and viruses ($n = 1$, 0.84%) using a cross-sectional design. Nearly half of the articles (47.3%) incorporated risk factor analysis. The majority

TABLE 2 Quality criteria used for the quality review.

Quality measure	Good quality	Medium quality	Poor quality
Subject selection	Unbiased selection of subjects	Biased selection of subjects is acknowledged and accounted for	Not acknowledged biased selection of subjects
Data analysis	Data analysis is appropriate	Limitations in data analysis are acknowledged and accounted for	Data analysis is not appropriate
Study method	Methods used are scientifically sound	Methods used are scientifically sound, although may not be the most appropriate methods	Wrong or inappropriate methods are used
Reporting of methods and results	Accurate description of methods	Some details of methods are lacking, but methods are understandable, and results remain valid	Methods are not clear or are incomplete
Reliability of results	Reported results are complete and seem accurate		Reported results are incomplete and/or inaccurate

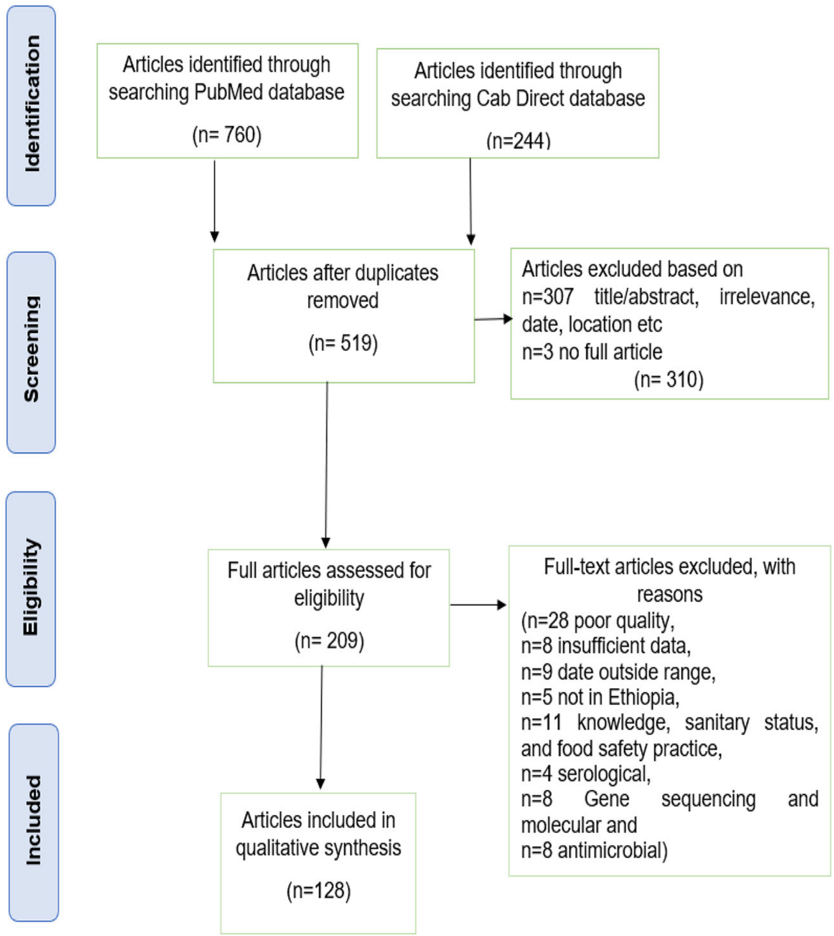

FIGURE 1
Flow chart of the process followed during the literature search for data extraction. The PRISMA flow diagram for the systematic review detailing the database searches, the number of abstracts screened, and the full texts retrieved.

of these publications ($n = 32$, 55.7%) concentrated on evaluating risks from food handlers, feverish patients in healthcare facilities, and randomly selected school students or community members. Of the 128 retained articles, 72 (56.25%) were mainly focused on detecting pathogens in animal source foods. Bacterial contamination was reported in food products in beef, dairy, and poultry value chains while parasites were reported from apparently healthy food handlers, from stool samples of patients of health care facilities and to some extent (4/10,40%) in vegetable value chain.

Figure 4 below, describes number of articles reporting a particular bacteria species.[2]

In terms of parasitic hazards, *Entamoeba*, *Giardia* and *Ascaris* were the most commonly studied hazards (Figure 5).

Study designs were often duplicated, to identify similar pathogens in similar populations. For example, most of the articles investigating pathogens on food handlers were conducted in student cafeterias of public universities. However, this may be more down to convenience, rather than intended inter-study comparability or the widespread use of established, optimized methods. The parasites investigated in these articles were similar, focusing on widely known FB parasites (e.g., *Ascaris lumbricoides*, *Giardia lamblia*, *Entamoeba histolytica*, *Taenia* spp. etc.).

3.3. Prevalence of foodborne hazards in the food value chains

Of the 82 articles that investigated hazards in food, the majority (64/82, 78%) focused on beef, dairy, vegetable poultry, and eggs value chains. Other value chains, such as camel, pork, fish, mutton, goat meat, fruits, crops, and street-vended locally made food (Sambusa, Bombolino, donat, and all doughnut variants) were the focus of 18 (22%) articles, the results of which are not reported on this paper (Ashenafi, 1995; Muleta and Ashenafi, 2001; Molla et al., 2005; Abdel Gadir Atif et al., 2006; Hiko et al., 2008; Kibret and Tadesse, 2013; Dulo et al., 2015; Garedew et al., 2015b; Eromo et al., 2016; Taye et al., 2016; Messele et al., 2017; Wendwesen et al., 2017; Tegegne et al., 2019) (Supplementary material). This section presents the literature findings per value chain or host, and per pathogen investigated.

2 *Salmonella* spp.—many studies did not provide the speciation of *Salmonella*, and it is possible some of these studies may or may not include Non-Typhoidal *Salmonella*., N.B. *Salmonella* spp. does not include Non-Typhoidal *Salmonella*, and *Escherichia coli* does not include *E. coli* O157:H7. N.B. articles may include more than one bacteria and parasite.

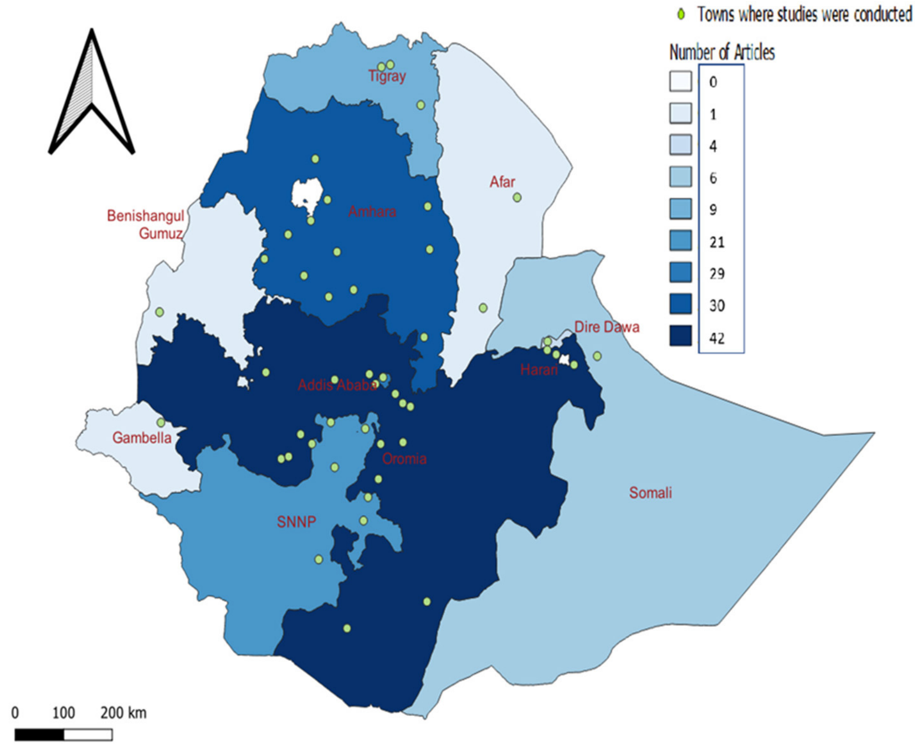

FIGURE 2
Spatial distribution of regions and towns where the studies were conducted. Concentration of included studies over regions in Ethiopia with dark blue color indicating the highest number of articles and light blue representing fewer number of articles. The green circle dots indicating the towns where the studies were conducted.

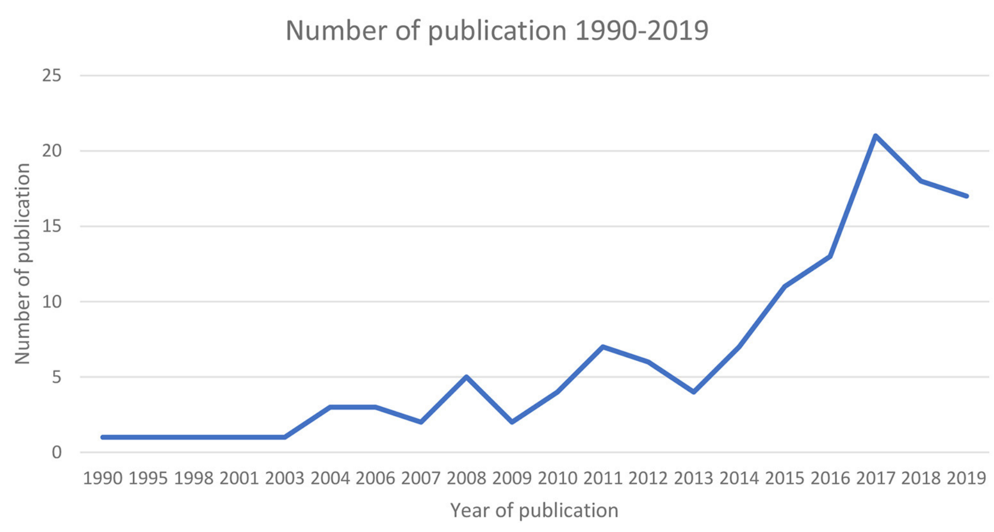

FIGURE 3
Number of retained publications on FBD in Ethiopia between 1990 and 2019. The solid line shows actual number of articles published in a particular year.

Pathogens are listed from the more frequently studied to the least, for each value chain or host.

3.3.1. Beef value chain

Close to one third of the articles investigated bacterial pathogens in the beef value chain (37/128, 28.9%).

3.3.1.1. *Salmonella* spp.

Eighteen articles (48.6%) reported information on *Salmonella* spp. *Salmonella* spp. contamination estimates ranged from 1 to 13% in raw beef samples collected from slaughterhouses in different parts of the country (Molla et al., 2003; Alemu and Zewde, 2012; Hiko et al., 2016, 2018; Edget et al., 2017; Wabeto et al., 2017; Ketema et al., 2018; Takele et al., 2018; Bersisa et al., 2019), and between

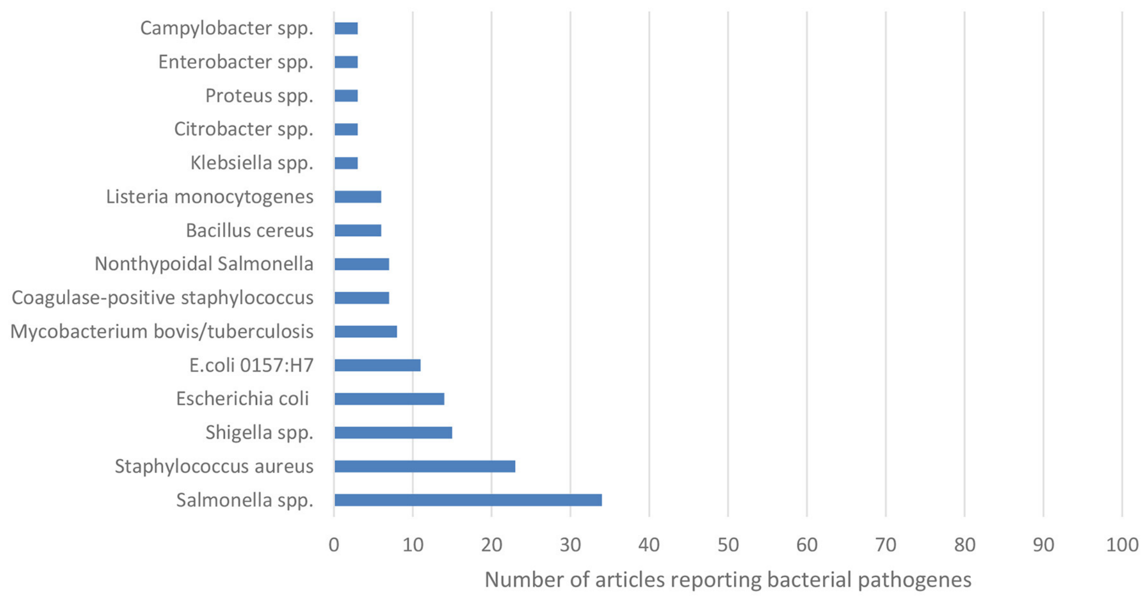

FIGURE 4
Number of articles reporting a particular bacterial pathogen. Numbers are derived from every article investigating on the pathogens. That is an article may report more than one bacteria species.

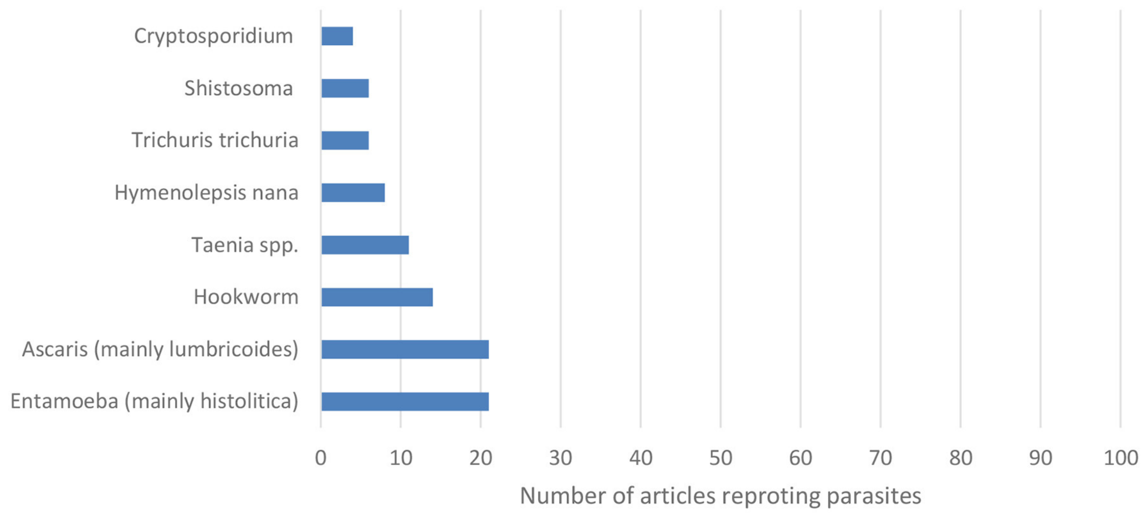

FIGURE 5
Number of articles reporting a particular parasite. Numbers are derived from every article investigating on parasites. That is an article may report more than one parasite.

1 and 35% in raw meat samples from butcheries and retail shops (Garedew et al., 2015b; Hiko et al., 2016, 2018; Edget et al., 2017). One study found 70% of fresh meat samples collected in butcher shops contaminated with *Salmonella* spp. (Azage and Kibret, 2017). Four articles investigated foodborne pathogens in "*kitfo*," a traditional Ethiopian raw (or lightly cooked) minced meat dish. About 9.8–12, 8, and 30% of "*kitfo*" samples in supermarkets, restaurants, and street vendors, respectively, were found to carry *Salmonella* spp. (Muleta and Ashenafi, 2001; Molla et al., 2003; Ejo et al., 2016; Dagnachew, 2017). One article investigated *Salmonella* spp. in processed meat (mortadella) and found 0.8% positive samples (Hiko et al., 2015).

3.3.1.2. *Escherichia coli*

Eleven articles (29.7%) reported contamination of beef with *E. coli*. About 5.5%–35.5% of raw beef samples from slaughterhouses,13.8% from restaurants, and 6%–29.4% from supermarkets were found contaminated with *E. coli* (Hiko et al., 2015; Edget et al., 2017; Messele et al., 2017; Bedasa et al., 2018; Bersisa et al., 2019). Kumar et al. (2014), reported that 62.5% of raw beef samples from butcher shops were positive for *E. coli*. Articles showed *E. coli O157:H7* detection ranged from 0.8 to 9% in raw beef samples from slaughterhouses (Hiko et al., 2016; Abdissa et al., 2017; Atnafie et al., 2017; Edget et al., 2017; Haile et al., 2017; Bedasa et al., 2018). The rate of contamination was higher in raw beef samples from butchers (2%—18%) (Kumar et al., 2014; Hiko et al., 2016; Atnafie et al., 2017; Beyi et al., 2017). *Escherichia coli O157:H7* was detected in raw beef and minced meat samples in (0%—3.1%) from retailer shops, restaurants, and supermarkets (Beyi et al., 2017; Edget et al., 2017; Bedasa et al., 2018).

3.3.1.3. *Mycobacterium bovis*

Five articles (13.5%) looked at *Mycobacterium bovis;* postmortem inspection studies conducted in abattoirs reported 0.8%—10% of carcasses showing mycobacterial lesions. The sensitivity and specificity of the routine postmortem examination method was also reported to be lower compared to detailed inspection and culturing. Specifically, 0.7–7.5 and 2.7–19.4% of carcass negative in routine postmortem examination were found to be positive in detailed examination and by culture, respectively (Asseged et al., 2004; Teklu et al., 2004; Demelash et al., 2009; Biffa et al., 2010; Aylate et al., 2013).

3.3.1.4. *Listeria monocytogenes*

In four (10.8%) articles investigating *L. monocytogenes*, 1.6%––2.6% of raw and minced meat samples at retailer shops in Addis Ababa were found to be positive (Molla et al., 2005; Gebretsadik et al., 2011; Derra et al., 2013; Garedew et al., 2015b). 6.7%—12% of raw meat and minced meat samples from restaurants in Gondar showed contamination with *L. monocytogenes* (Garedew et al., 2015b).

3.3.1.5. *Staphylococcus spp.*

According to findings in three (8.1%) articles, up to 11.6% of samples from slaughterhouses and 19.7% from butchers were contaminated with *Staphylococcus aureus* (Beyene et al., 2017; Adugna et al., 2018; Bersisa et al., 2019). Authors indicated continuous contamination throughout transportation from slaughterhouses to butcher shops (Tolosa et al., 2016; Beyene et al., 2017). Beyene et al. (2017) reported 10.6% carcass swabs from slaughterhouse were positive for coagulase-negative *Staphylococci* in beef.

3.3.1.6. *Shigella* spp.

Three articles (8.1%) investigated *Shigella* spp. in beef. None of the beef samples ("kitfo" and raw meat) collected from restaurants and slaughterhouses were positive for *Shigella* spp. (Muleta and Ashenafi, 2001; Bersisa et al., 2019). However, 11% of raw beef samples from butchers were found to be contaminated with this pathogen (Garedew et al., 2016).

3.3.2. Dairy value chain

Bacterial pathogens in dairy value chains were reported in 23.4% (30/128) of the articles reported.

3.3.2.1. *Staphylococcus* spp.

Different *Staphylococcus* spp. were reported in 15 articles (50%). *Staphylococcus aureus* was common in milk at the farm (14.3%—73.2%) and up to 80% of milk samples at collection centers carried this pathogen (Almaw et al., 2008; Lakew et al., 2009; Daka et al., 2012; Haftu et al., 2012; Makita et al., 2012; Tigabu et al., 2015; Abebe et al., 2016; Tolosa et al., 2016; Ayele et al., 2017; Beyene et al., 2017). Coagulase-negative *Staphylococcus* was found in 5%—15% of milk samples collected from farms (Almaw et al., 2008; Lakew et al., 2009; Beyene et al., 2017). Baby bottle (made of cow milk, powder, and cereal blend) samples collected from outpatient infants visiting public clinics in Addis Ababa were contaminated with *S. aureus* (64.2%—68.3%) (Erku and Ashenafi, 1998).

3.3.2.2. *Listeria* spp.

Six (20%) articles looked at the presence of *Listeria* spp. in the dairy value chain. *Listeria monocytogenes* was detected in 4%—13% of raw milk samples collected from retailers (Gebretsadik et al., 2011; Garedew et al., 2015b). While pasteurization should kill this bacterium, an article reported that 20% of pasteurized milk samples from retailers carried this pathogen, likely derived from cross-contamination during processing (Seyoum et al., 2015). However, another article reported that none of the pasteurized milk samples at restaurants carry *L. monocytogenes* (Garedew et al., 2015b). Contamination rate of *L. monocytogenes* in locally produced cottage cheese was low (0%—1%) (Molla et al., 2005; Gebretsadik et al., 2011; Garedew et al., 2015b). On the contrary, 27% of cheese and 5% of yogurt from supermarkets were positive for *L. monocytogenes* (Seyoum et al., 2015). Also, two articles reported that 15%—20% of ice cream samples from retailers were contaminated with *L. monocytogenes* (Molla et al., 2005; Garedew et al., 2015b).

3.3.2.3. *Bacillus cereus*

According to five (16.7%) articles, 0.6 to 0.8% of milk samples collected from producers were positive for *B. cereus* (Almaw et al., 2008; Getahun et al., 2008). Up to 63% of milk samples from markets were contaminated with *B. cereus* (Ashenafi, 1990; Abraha et al., 2017). Erku and Ashenafi (1998) also identified contamination of baby bottle contents with *B. cereus*, including 38.3% of cow's milk samples, 42.8% in cereal blend and none in powder milk.

3.3.2.4. *Salmonella* spp.

Five studies (16.7%) investigated *Salmonella* spp. in the dairy value chain. Three percent to 20% of milk samples collected at dairy farms carried *Salmonella* spp. (Addis et al., 2011; Tadesse and Dabassa, 2012). While *Salmonella* spp. was absent in dairy products (cottage cheese and cream) or pasteurized milk, 6% of raw milk samples from retailers were found to be contaminated (Ejo et al., 2016). Erku and Ashenafi (1998) also identified *Salmonella* contamination of baby bottle contents (3.3% of cow's milk and 7.1% of cereal blends), but not in powder milk.

3.3.2.5. *Mycobacterium bovis*

Mycobacterium species were the focus in four (13.3%) articles. One article reported that 13% of farms with tuberculosis reactors had milk contaminated with *M. bovis* (Fetene et al., 2011). Between 3%—14% of tuberculosis infected animals were reported to shed *M. bovis* in their milk (Ameni and Erkihun, 2007; Elias et al., 2008).

3.3.2.6. *Escherichia coli*

Articles on *E. coli* were seen in four (13.3%) recently published articles on the dairy value chain (since 2017). Articles on milk found *E. coli* contamination increasing from 7% on farm to above 60% at retailer milk shops selling raw milk. This increase was attributable to post-farm contamination and lack of cold chain (Disassa et al., 2017; Bedasa et al., 2018; Haftay et al., 2018; Messele et al., 2019). An article reported that none of the pasteurized milk samples collected at cafeterias, restaurants, and supermarkets were contaminated with *E. coli* while milk derived products, like cheese (40%) and yogurt (25.7%), contained *E. coli* (Bedasa et al., 2018). Two articles detected *E. coli O157:H7* in pasteurized milk (5.7%) sampled from cafeterias, restaurants, open markets, and supermarket but *E. coli O157:H7* was not detected in yogurt and cheese samples (Disassa et al., 2017; Bedasa et al., 2018).

3.3.3. Poultry and egg value chains

Ten (7.81%) of the included articles reported pathogens in poultry value chain. An article on chicken meat detected *E. coli* in 37% of samples from slaughterhouses (Messele et al., 2017). Off the 452 chicken meat samples from retailer shops, 11.5% were contaminated with Non-typhoidal *Salmonella* spp. (Molla et al., 2003). *Listeria monocytonenes* was detected in 1.9% of raw chicken meat samples collected from retailers (Molla et al., 2005). *Salmonella* spp. was isolated in 2.6%−18% of egg content and egg sandwich samples collected from either retailers, producers and restaurants (Muleta and Ashenafi, 2001; Bayu et al., 2013; Ejo et al., 2016; Kemal et al., 2016; Taddese et al., 2019). *Listeria monocytogenes* was detected in 4.3% of eggs sampled at retailer (Gebretsadik et al., 2011).

3.3.4. Vegetable value chain

Ten (7.81%) of the included articles investigated hazards in vegetable value chain. High parasite contamination rates were reported for a range of raw vegetables. Presence of at least one type of parasite (*A. lumbricoides, E. histolytica/dispar, G. lamblia*) in samples of raw vegetables (including green paper, carrot, tomato, cabbage, lettuce) was reported in 49%−71% samples (Bekele et al., 2017; Alemu A. S. et al., 2019; Bekele and Shumbej, 2019). Two articles looked at bacterial hazards in vegetables and reported *Salmonella* spp. in 0 to 10% of samples and *Shigella* spp. in 10%−20% of samples (Guchi and Ashenafi, 2011; Eromo et al., 2016). Contaminated irrigation water attributed to open air defecation was stated as a possible source of vegetable contamination at the farm (Alemu G. et al., 2019).

3.3.5. Prevalence of hazards in the environment

The selected articles included studies looking at food safety hazards in the environment of beef slaughterhouses (six articles), butcheries (three articles) and milk shops (two articles). However, these studies had small samples sizes (2–30 samples per study).

In slaughterhouses, *Salmonella* spp. was detected in workers hand swab (2%−50%), surfaces (50%), environmental pooled samples (6.7%), aprons (7.1%), knives (7.7%), room floor (23.5%), refrigerator (10%), beef transport truck (36.4%) and tap water (8.3%) used for washing (Sibhat et al., 2011; Edget et al., 2017; Hiko et al., 2018). *Escherichia coli* was present on 50, 23, and 50% of samples from equipment, environment pooled samples and workers hand swab, respectively (Edget et al., 2017; Bersisa et al., 2019). *Escherichia coli O157:H7* was identified on knife swabs (13.3%) and in environmental pooled samples (6.6%) at slaughterhouses (Atnafie et al., 2017; Edget et al., 2017). *Staphylococcus* spp. (*S. aureus*, *Staphylococcus intermedius*, and *Staphylococcus hyicus*) were detected in swab samples from knives (16.7%−33.3%) and hanging materials (33.3%−50%) (Beyene et al., 2017).

About 0%−6.6% cutting board swabs samples from butchers were positive for *E. coli O157:H7* (Atnafie et al., 2017; Beyi et al., 2017). Bersisa et al. (2019) reported 11.1% cutting board swab and 5.5% of knives swab in butchery shops positive for *Salmonella* species. In One article *E. coli* was found in 25% and 19.4% of cutting board and knives swab. This study also reported presence of other bacteria (*Klebsiella, Proteus*, and *Shigella* species) in butchery shops (Bersisa et al., 2019).

Articles found *S. aureus* contamination rate ranging between 12 and 25% in samples from milk buckets. Same rate was reported in milk tank samples (Ayele et al., 2017; Beyene et al., 2017).

3.4. Prevalence in clinically healthy food operators

Articles investigated (26/128, 20%) carriage of bacteria and parasites by food handlers, including workers in universities cafeteria (9/26, 34%), workers at dairy farms, abattoirs, and butchery (9/26, 34%), and workers in other food establishments (hotels, restaurants, bars, and cafeterias; 6/26, 23%). Nineteen (73%) and 12 (46%) of the 26 articles, respectively identified bacteria (mainly *Salmonella* spp., *Shigella* spp. and *S. aureus*) and parasites from stool samples collected from apparently health food handlers. Table 3 presents the range of contamination with different foodborne pathogens reported in the selected articles.

One article reported 6% of stool samples from abattoir staff carrying non-typhoidal *Salmonella* spp. (Molla et al., 2003).

Four articles reported isolation of different bacteria species on worker's hand swab samples. Results showed these swab samples were frequently positive for *Salmonella* spp., having been found in 24% of samples from butchers' shops operators and 30%−50% of samples of slaughterhouse personnel (Garedew et al., 2015a; Edget et al., 2017; Hiko et al., 2018). *Shigella* spp. was present in 13% of hand swab samples from butcher shops. *Staphylococcus aureus* was reported in 25%−32% of dairy farm milkers, and coagulase-negative *Staphylococcus* in 12%−16% of dairy and beef farm workers' hands. *Escherichia coli* was found in 50% of hand swabs taken from slaughterhouse workers (Garedew et al., 2016; Ayele et al., 2017; Beyene et al., 2017; Edget et al., 2017).

Swabs from fingernails examined for the presence of bacteria and internal parasites were often positive for coagulase-negative *Staphylococcus* (12%) and *S. aureus* (5%) (Mengist et al., 2018a).

3.5. Prevalence in non-food operators

Parasites were the most common foodborne hazard investigated in stool samples from children at school, patients visiting health centers and household members of community, including *A. lumbricoides* (4.2%−28%), *G. lamblia* (0.8%−10%), *Entamoeba* (6.7%−7.8%), *Trichuris trichuria* (0.4%−5.6%), hookworm (0.6%−1.3%) and other parasites (Desalegn et al., 2014; Alelign et al., 2015; Jejaw et al., 2015; Gebresilasie et al., 2018; Gizaw et al., 2018; Mekonnen and Ekubagewargies, 2019).

In stool samples from adult patients (mostly with enteric signs), *Salmonella* spp. (non-typhoidal *Salmonella* 7.18%−39.7%, typhoidal *Salmonella* 0.8%−39.7%, and unspecified *Salmonella* species 10.7%), *Shigella* (1.13%−13.86%), *Campylobacter* spp. (*Campylobacter jejuni* 7.3%−11.89%, *C. coli* 0.6%−3.5%), and internal parasites (*Entamoeba*, *Giardia* and *Cryptosporidium* in 24.6%−35.6% of the patients) were identified (Kassu et al., 2007; Ewnetu and Mihret, 2010; Tafa et al., 2014; Eguale et al., 2015, 2018;

TABLE 3 Pathogens detected from stool samples of food handlers working in food establishments.

Pathogens	%Min	%Max	References
Ascaris lumbricoides	1.1	45	Gebreyesus et al., 2014; Aklilu et al., 2015; Mama and Alemu, 2016; Solomon et al., 2018; Alemu A. S. et al., 2019; Asires et al., 2019; Bafa et al., 2019; Eshetu et al., 2019; Kebede et al., 2019
Entamoeba histolytica	2.9	39.5	Gebreyesus et al., 2014; Aklilu et al., 2015; Mama and Alemu, 2016; Gezehegn et al., 2017; Solomon et al., 2018; Alemu A. S. et al., 2019; Asires et al., 2019; Bafa et al., 2019; Eshetu et al., 2019; Kebede et al., 2019; Kumma et al., 2019
Taenia spp.	0.5	14.7	Gebreyesus et al., 2014; Aklilu et al., 2015; Mama and Alemu, 2016; Solomon et al., 2018; Alemu A. S. et al., 2019; Bafa et al., 2019; Eshetu et al., 2019; Kebede et al., 2019
Giardia lamblia	0.4	10.4	Gebreyesus et al., 2014; Aklilu et al., 2015; Mama and Alemu, 2016; Gezehegn et al., 2017; Solomon et al., 2018; Alemu A. S. et al., 2019; Asires et al., 2019; Bafa et al., 2019; Eshetu et al., 2019; Kebede et al., 2019; Kumma et al., 2019
Shigella spp.	0	10	Aklilu et al., 2015; Mama and Alemu, 2016; Marami et al., 2018; Mengist et al., 2018b; Bafa et al., 2019; Getie et al., 2019
Hookworm	1	8.1	Aklilu et al., 2015; Gezehegn et al., 2017; Solomon et al., 2018; Alemu A. S. et al., 2019, Asires et al., 2019; Bafa et al., 2019; Eshetu et al., 2019; Kumma et al., 2019
Salmonella spp.	0.9	6.3	Yemane et al., 2014; Aklilu et al., 2015; Mama and Alemu, 2016; Marami et al., 2018; Mengist et al., 2018b; Bafa et al., 2019; Getie et al., 2019
Enterobius vermicularis	2.3	4.9	Asires et al., 2019; Bafa et al., 2019
Trichuris trichuria	0.5	1.7	Aklilu et al., 2015; Bafa et al., 2019

Lamboro et al., 2016; Berhe et al., 2018; Deksissa and Gebremedhin, 2019). Acute gastroenteritis patients were positive for norovirus (25.3%) and less commonly for sapovirus (4.2%) (Sisay et al., 2016).

Among prison inmates in north Ethiopia, intestinal parasites were detected in 40% of sample population and the dominant parasite was *E. histolytica/dispar* (n = 60, 22.2%) followed by *G. lamblia*, 39 (14.4%) (Mardu et al., 2019). In Gondar, 37.0% of apparently healthy street dwellers carried *A. lumbricoides* (Moges et al., 2006).

An article exploring the risk of congenital transmission of *Toxoplasma gondii* showed that 85% of pregnant women monitored in a hospital in Ethiopia had seroconverted by the third trimester of pregnancy (Gelaye et al., 2015). In another article, 31.3% of pregnant women attending antenatal care at Gondar were infected with one or more intestinal parasites. The most common single and mixed parasites observed were *E. histolytica* (38.1%) and *A. lumbricoides* (24.6%) (Kumera et al., 2018). *Entamoeba histolytica*, *G. lamblia*, *Taenia species*, *A. lumbricoides*, and *Cryptosporidium parvum* were mainly identified in one article which determine the presence of intestinal parasites and associated risk factors among HIV/AIDS patients (Gedle et al., 2017).

4. Discussion

The literature on FBDs hazards in Ethiopia is patchy, mostly consisting of small *ad hoc* local investigations, with no single comprehensive overview of the topic. This is not a unique feature of Ethiopia and has been reported across Africa (Alonso et al., 2016). The majority of the studies were performed in Oromia, Amhara, Addis Ababa and Southern Nation Nationalities People (SNNP) region which may reflect local outbreaks occurring more frequently in this area due to presence of many food establishments and consumers (Addis Ababa and surrounding Oromia region). It may also reflect a biased picture, with studies performed where relevant research groups happen to be based. The Ethiopian FBD literature has focused on measuring food contamination with key biological hazards, especially bacteria, which are suggested to account for much of the FBD burden (Havelaar et al., 2015).

The identified articles focusing on the prevalence of FB hazards in humans mostly focused on parasitic infection in children (sampled from schools, health centers and community households), adult patients with enteric signs, and susceptible populations (pregnant women and HIV/AIDS patients). A few studies looked at, and reported findings from, presence of *Salmonella* spp. (typhoidal and non-typhoidal), *Campylobacter* spp. and *Shigella* spp. in blood and stool samples.

Some of the most important bacteria in terms of public health (e.g., non-typhoidal *Salmonella*, *L. monocytogenes*, and *Campylobacter* spp.), compared to *Salmonella*, *Staphylococcus* and *Shigella*, have received, to date, little attention in the country. Assessments of the amount of these bacterial pathogens present in food and food environments are very rare. Few of the included articles which reported pathogens in environment do not take representative samples which compromises the quality of work. However, such quantitative assessments are needed to estimate consumer-pathogen exposure and health and economic risk from FBD (Zaneti et al., 2021). The outputs of such assessments are a critical part of food safety management systems and are important for countries to prioritize food safety areas of interventions.

Hazards that are harder to study such as chemicals, viruses, and certain bacteria like *Campylobacter* spp., were investigated less frequently. This is a well-known challenge in low- and middle-income countries, where resources and facilities for diagnostics are often limited. In our review, we observed an increase overtime in the number of articles on FBD. This could be suggestive of an increased interest in the topic over the past few years, which could have been matched with increased funding for research in this area. It could also be a result of the quality of articles having improved overtime, meaning that an increasing proportion of identified papers would have passed the review's quality assessment which is evidenced by increased number of included (five-fold) than excluded articles from 2015 to 2019. Both options are encouraging and suggest that more attention is being given to food safety and FBD among the national scientific and the international donor communities.

Foodborne pathogens, such as intestinal parasites, *E. coli* including O157:H7, *Salmonella* species and *S. aureus,* were commonly isolated on different foods and at different levels in various value chains. This is not surprising as the level of hygiene and the application of good practices of food quality management are highly variable across the country, but in general are limited, especially in rural areas. Even simple equipment, refrigeration, and key infrastructure, such as a reliable power and clean water supply are not available in informal food supply chains, where most people get their food (FAO, 2007; Glatzel, 2017) Even in the more up-market outlets, including supermarkets and restaurants, food safety is a challenge, given both the limited infrastructure and the relative lack of quality suppliers and quality management.

Beef and milk are widely consumed in Ethiopia and were often the target of the included articles. Although consumption of raw beef is a common practice in Ethiopia, hygiene standards in abattoirs are poor, with high levels of *E. coli* and *Salmonella* spp. For most pathogens, contamination rates are lower for samples of product collected in slaughterhouses compared to subsequent steps in the supply chain. In the case of meat, the butcher appears to be a node in the chain where levels of contamination tend to increase. Unhygienic practices, both at the slaughterhouses and retail shops, which underpin the public health risk associated with meat-borne pathogens, have been reported in Ethiopia (Gutema et al., 2021).

A variety of articles assessed hygiene and bacterial contamination of milk, typically finding high microbial contamination. Lack of cold chain and the presence of technical limitations by dairy operators were frequently reported as reasons for poor microbial quality of milk (Disassa et al., 2017; Bedasa et al., 2018; Haftay et al., 2018; Messele et al., 2019). *Escherichia coli*, *S. aureus*, and *Bacillus* spp. were the most prevalent bacteria identified in the milk value chain. A recent article showed that the proportion of contamination was significantly lower in milk collected from dairy farms when compared to milk from vendors (Berhe et al., 2020). Generally, presence of *E. coli*, *E. coli 0157:H7*, *Bacillus* spp, and *Listeria* spp was more likely in raw milk samples collected from retailers than those from producers, indicating that milk microbial quality may derived from contamination at various points of the value chain post-harvest, and that storage conditions are facilitating bacterial growth. The literature also showed contamination by foodborne pathogens of various milk derived products; it is worth noting that, in Ethiopia, these products are typically consumed without any further processing at home, meaning that no steps that could reduce the pathogen load are taken before consumption (Beyene et al., 2017; Amenu et al., 2019; Mebrate et al., 2020; Deneke et al., 2022). The presence of hazards in pasteurized milk reported in some of the studies is concerning. Pasteurization is a heat-treatment process used to decrease the bacterial load of milk. Presence of bacteria in pasteurized milk is indicative of failures in the pasteurization process, cross- or re-contamination post-pasteurization or inadequate storage after pasteurization (Garedew et al., 2012; Tekilegiorgis, 2018).

The importance of beef and milk processing points and practices to food safety, are highlighted in articles from beef and dairy value chains. Foodborne pathogens originating from fecal contamination during slaughter, such as *Salmonella* spp. and *E. coli,* can potentially contaminate the carcass and spread to the cut or raw meat intended for further processing, causing a major public health threat (Soepranianondo et al., 2019). This is supported by several of the included articles which show presence of different bacterial species in samples collected from different environmental surfaces at beef slaughterhouses (Hiko et al., 2015; Edget et al., 2017; Messele et al., 2017; Bedasa et al., 2018). However, extrapolation of these findings to the entire country could not be reliable due to the small sample sizes and geographical coverage in the majority of the articles reviewed.

Further evidence of sources of contamination along the food value chains is presented by the microbial investigations of apparently healthy food handlers. These records confirm the potential role of food handlers in the spread of FBD (Dagnew et al., 2012). Food handlers with poor health and hygiene may be infected with a wide range of foodborne pathogens and have already been demonstrated to play a role in transmitting disease to the public (Khurana et al., 2007). This is an important area in food safety research, and our results show that it deserves greater attention in the country.

There were no published assessments of FBD burden and incidence in humans. The SLR only included published literature but did not consider hospital records that are unpublished (gray literature), therefore, the study cannot assess the true burden of FBD. However, it is true that in Ethiopia, many foods are consumed raw (beef, milk) (Dagne et al., 2022; Deneke et al., 2022), therefore the risk of FBD is higher if the prevalence of pathogens in the product is high. Disease burden and cost estimates are critical for risk-based decision-making. Estimating the incidence of illness caused by FBD is a gap to be addressed in the future.

It is important for policy makers to know the burden of a disease in order to allocate appropriate resources for its control. However, FBD burden is harder to measure than food contamination, either requiring an effective FBDs surveillance system, which does not exist in many low- and middle-income countries, or well-designed, large epidemiological studies. These studies require complex analysis to overcome issues of under-reporting and imperfect diagnosis.

We acknowledge that the search being done only in two databases and required articles to be available electronically some articles may not have been detected. Therefore, information from gray literatures is not included. However, all quality research articles are expected to have been captured and inclusion of electronically available articles as a limitation to this review. Only 10% ($n = 13$) of the 128 articles were reviewed in pairs. This may also be one limitation of this review. In addition, publications since 2019 recent years are not considered due to time constraints and because the review was performed at the time to inform overarching research projects that started around 2019. Lastly, we cannot exclude the possibility that the results from our review are affected by publication bias, but we have no ability to estimate the magnitude of that potential bias.

5. Conclusion

In conclusion, little has been done to assess FBD burden in Ethiopia. The scientific literature reveals high levels of contamination, with both bacterial and parasitic pathogens, and shows fundamental gaps in food safety for many food value chains. Pathogens that are hard to assess are largely over-looked. In both beef and dairy value chains bacterial contamination was observed with increasing prevalence from farm/slaughterhouse to point of sale. Given the findings, the following recommendations are made to improve food safety in Ethiopia:

1. More systematic and ongoing evaluation of contamination should be implemented to provide a comprehensive overview of the topic including in Benishangul-gumuz, Afar, and Somali regions.
2. Chemicals, viruses and some of the most important bacteria which are of public health concern should be investigated more.
3. Future research on FBD should thoroughly investigate risk factors.
4. The potential role of food handlers and food environment should be investigated in detail by considering representative samples.
5. In addition to assessing presence or absence of hazards, quantitative assessments of the amount of hazards present in food and food environments is required.
6. Due attention should be given to vegetables, fruits, crops, fish, sheep, goats, and camel value chains.
7. Incidence of human FBDs or resulting health and economic impacts should also be center of attention.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

Conceived and designed the study protocol: DG, SA, FMu, KR, JL, KA, and MD. Carried out the screening and data extraction from records: DG, SA, FMu, KR, JL, LG, KA, FMa, PU, TG, and GI. Drafted the manuscript: LG, SA, and TK-J. All authors read, reviewed, and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1058977/full#supplementary-material

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