Frontiers in Sustainable Food Systems

TYPE Systematic Review
PUBLISHED 20 October 2023
DOI 10.3389/fsufs.2023.1232992

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OPEN ACCESS

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RECEIVED 01 June 2023
ACCEPTED 05 October 2023
PUBLISHED 20 October 2023

CITATION
Dinede G, Amenu K, Alonso S, Gazu L, Mutua F, Roesel K, Lindahl JF, Sousa FM, Ulrich P, Guadu T, Dione M, Ilboudo G, Knight-Jones TJD and Grace D (2023) Foodborne hazards in food in Burkina Faso, 1990–2019: a systematic review and meta-analysis.
Front. Sustain. Food Syst. 7:1232992.
doi: 10.3389/fsufs.2023.1232992

Foodborne hazards in food in Burkina Faso, 1990–2019: a systematic review and meta-analysis

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Background: Foodborne diseases impose substantial public health burden and jeopardize socio-economic development worldwide. While accurate information on foodborne hazards is needed for informed decision in food safety interventions, such information is scarce in developing countries such as Burkina Faso. We conducted a systematic review and meta-analysis of studies reporting foodborne hazards in foods in Burkina Faso to describe the present knowledge of the situation.

Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline was used to conduct this review. Abstracts were searched in PubMed and CAB direct between 1 January 1990 to 30 September 2019. We used random-effects models to estimate pooled prevalence and I^2 values to measure heterogeneity between studies.

Results: 188 articles were identified, of which 14 are included in this review: 12 were on bacterial hazards (*Salmonella, Campylobacter, Staphylococcus, E. coli, Shigella*), three on fungal hazards and one on parasitic hazards (*Toxoplasma gondii*). The overall pooled prevalence of *Salmonella* spp. was 13% (95% CI: 8–21), the highest in lettuce: 50% (95% CI: 30–70) and the lowest in milk: 1.2% (95% CI: 0–5), demonstrating substantial variation among the studies (I^2 =85, 95% CI: 79–90%, p <0.01). *Campylobacter* spp. was reported in chicken carcass, with 50% of the samples being positive. The overall pooled microbial load of *Staphylococcus* in the studied food samples was 3.2 log (95% CI: 2.8–3.6) CFU per g or ml of food, the highest in poultry samples: 4.5 log (95% CI: 2.8–6.2) CFU per g or ml of food. The overall pooled prevalence of *Escherichia coli (E. coli)* was 40% (95% CI: 29–51), the highest in beef intestines: 62% (95% CI: 22–91) and the lowest in dairy products: 31% (95%

CI: 17–50), showing substantial variation across the studies (I^2 =86, 95% CI: 80–90%, p <0.01).

Conclusion: Our results showed widespread contamination of foods with foodborne hazards across various food value chains indicating poor hygienic handling of foods, raising consumers' health risk due to foodborne illnesses from the foods. We recommend promotion of awareness creation in food safety and improved monitoring of hazards in food.

KEYWORDS

foods, foodborne disease, foodborne hazard, food poisonings, food safety, Burkina Faso

1. Introduction

Consumption of foods contaminated with foodborne hazards causes more than 200 diseases, ranging from diarrhea to cancers (World Health Organization Food safety, n.d.). In 2010, 31 foodborne hazards caused 600 million foodborne illnesses worldwide-almost one in ten people in the world-and 420,000 deaths every year, resulting in the loss of 33 million healthy life years, with the greatest *per capita* burden falling on the subregions in Africa. Children under the age of five years bore 40% of the burden (World Health Organization, 2015). The burden of foodborne illness is higher in the subregion of Africa with high child and adult mortality (AFR D), to which Burkina Faso belongs, compared with other subregions (Havelaar et al., 2015).

Food-producing animals (e.g., cattle, poultry, pigs and fish) are the main reservoirs for several important foodborne pathogens (Gal-Mor et al., 2014; Ferrari et al., 2019). Vegetables, water and beverages are also high risk foods for foodborne pathogens (Berger et al., 2010; Paudyal et al., 2017; Dinede et al., 2020). Moreover, produce and animal source foods consumption is expected to markedly increase in low-and middle-income countries (LMICs), raising food safety concerns unless appropriate food safety management is implemented (Grace et al., 2020).

Although consumers' concern about food safety has been increasing in LMICs, food safety management is neglected, with especially low compliance with food safety regulations in the traditional or informal markets, where most people buy food (Grace, 2015). Risk factors for unsafe food include lack of clean water used for cleaning and processing of food; poor food-production processes and food-handling (including inappropriate use of agricultural chemicals); inadequate food storage infrastructures; and inadequate enforcement of regulations (World Health Organization, 2015).

Several studies show that food handlers in Burkina Faso have poor knowledge about food safety (Barro et al., 2002; Ilboudo et al., 2009; Somda et al., 2018). Poor sanitary practices during food production, sale, preparation, cooking and servicing leads to microbial contamination. Studies in Burkina Faso have shown that foods obtained from retail markets are often contaminated with foodborne hazards, with food handlers in these retail markets frequently having poor hygienic practices while handling foods, including using unclean water for cleaning and processing of foods and storing food at inappropriate temperatures (Kagambèga et al., 2012a,b; Somda et al., 2018).

Food safety authorities are responsible for food safety monitoring to help safeguard consumers' health. In high-income regions, for example in the European Union (EU), responsible bodies for food safety issues set out sampling strategies and acceptable standards for microbiological hazards in foods sold, with removal from market and potential prosecution if these standards are exceeded (European Commission Regulation, 2005). Such monitoring schemes need comprehensive information on food safety, including the risk of different foodborne hazards, to inform public health policies and implement interventions that contribute to reducing foodborne disease burden. Systematic reviews reporting food hazards have been conducted in some African countries to provide synthesized information on food contamination in these countries, which help inform policy and decision making by different stakeholders (Alonso et al., 2016; Paudyal et al., 2017; Oduori and Kwoba, 2022; Gazu et al., 2023). However, such information is lacking in Burkina Faso. Given the paucity of food hazards information in this country, this Systematic Literature Review (SLR) was conducted to summarize the evidence on hazards in foods in Burkina Faso from 1990 to 2019 through systematic review of available literature reporting foodborne hazards in foods. Specific objectives of the review include describing: (1) the trends of food safety research in the review period; (2) the hazards studied including their types and associated contamination levels in the food samples and (3) to estimate a pooled contamination levels (prevalence, microbial load) of the hazards in different food samples through meta-analysis, where applicable.

2. Methods

2.1. Research questions

This systematic review and meta-analysis aimed to address the following research questions related to hazards in foods in Burkina Faso during the review period:

a) What potential foodborne hazards (biological and chemical hazards) have been reported in foods in Burkina Faso?

b) What is the contamination level (proportion of foods with hazards or microbial loads of the hazards in foods) of these hazards in foods in Burkina Faso?

2.2. Search strategy and study selection

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Page et al., 2021) was used to conduct this systematic review. We searched for abstracts published in English or French in PubMed and CAB Direct databases from January 1, 1990 to September 30, 2019. We used different search terms including, but not limited to, the following keywords: "foodborne," OR "food borne" OR "food-borne," OR "food safety," OR "food related," OR "food associated," OR "food derived," "food* illness" OR "food* disease*" OR "food* intoxica*" OR "food* poison*," "food pathogen" OR "food* microb*" OR "food* vir*" OR "food parasit*" OR "food toxin," AND "Burkina Faso." Search terms kept broad and more general to allow retrieving all the literature reporting hazards in different aspects: proportion of foods with hazards, microbial loads of hazards in foods and so on.

We included studies (that followed probabilistic approach in their study design) that reported foodborne hazards in foods (prevalence or microbial load) in Burkina Faso. We excluded studies focusing exclusively on non-foodborne disease hazards and antimicrobial resistance. We also excluded studies reporting hazards exclusively in non-foods items, such as in animal feces, animal serology, or carriage in vectors. Studies outside Burkina Faso and papers on basic science were also excluded. Furthermore, studies reporting literature review findings were excluded.

Searched abstracts were imported to Mendeley to remove duplicates. Two reviewers then independently screened the titles and abstracts of the articles against the given inclusion and exclusion criteria. Articles considered relevant by both reviewers were kept and those considered relevant by just one reviewer were reviewed again by a third reviewer, to decide on their eligibility. Then, full text articles of relevant studies were retrieved.

Full text articles were assessed for their quality against the set criteria, which includes use of (1) scientifically sound methods, (2) appropriate laboratory procedures, (3) appropriate data analysis and, (4) reporting of accurate results. Articles were rated 'good', 'medium' and 'poor' using detail criteria indicated in Table 1. Only studies rated good, and medium were considered for inclusion.

One of the two reviewers extracted the required data which included authors, publication year, title, study design, study site, sampling points, food sample types, sample size, hazard group, and specific hazards.

2.3. Data analysis

We described study characteristics using descriptive statistics (frequencies). A random-effects model (DerSimonian–Laird method) was used to estimate a pooled prevalence and microbial load, and the corresponding 95% confidence intervals (95% CI). Heterogeneity across the studies was assessed using the Higgins I^2 statistic, with 25, 50, and 75% values of I^2 showing low, moderate and high heterogeneity, respectively (Higgins et al., 2003). Sources of heterogeneity across the studies were assessed using subgroup analysis, a value of p for this test of less than 0.1 indicates a statistically significant subgroup effect (Richardson et al., 2019). Studied food samples were grouped as chicken, cattle, sheep, fish, pig, dairy products, plant, vegetable, fruit, cereal, legume, and water samples, with this classification being used for our subgroup meta-analysis, where applicable. But samples from chicken were classified as chicken meat and those from cattle and sheep were classified as meat for subgroup meta-analysis purpose. That is hazard contamination level reported in one of these subgroups was summarized as subgroup pooled estimate, which contribute to the overall pooled estimate. A study reporting a given hazard in multiple sample types was used as different records (studies) for the

TABLE 1 Quality assessment checklist for articles included in the systematic review and meta-analysis of food hazards in Burkina Faso, 1990–2019.

No.	Quality criteria	Good	Medium	Poor
1	Scientifically sound methods	(1) Sampling points and study settings, and study subjects were described in detail and clearly (2) Appropriate sampling techniques were used considering efforts to address potential study subject selection bias (3) Adequate sample size	(1) Sampling points and study settings, and study subjects were indicated, but somewhat unclear (2) Sampling technique not well described; subjects selection bias inadequately addressed but remains acceptable (3) Adequate sample size	(1) Sampling points and study settings, and study subjects were not described at all (2) Sampling technique used was unclear or not valid (3) Inadequate sample size
2	Appropriate laboratory procedures	Standard laboratory methods were used	Valid or acceptable laboratory methods were used	Laboratory method is inappropriate, unacceptable
3	Appropriate data analysis	Appropriate statistical methods were used for data analysis	Acceptable statistical analysis but with some limitations. Limitations were acknowledged and accounted for.	Inappropriate statistical analysis
4	Accurate results	Results were complete and accurate	Results remain valid	Results were incomplete or inaccurate

meta-analysis-multiple entry of a given study in the meta-analysis. Forest plot was used to visualize outputs of meta-analysis. Prevalence estimate from a single study was kept in the meta-analysis (shown in forest plots) as it would contribute to the overall pooled estimate. The analysis was done using R (version 4.1.3, The R Foundation, Vienna, Austria), with *meta* package (version: 5.5–0) (Team, R.D.C, 2022).

3. Results

3.1. Searching and selecting of the studies

A total of 188 unique records were identified from PubMed and CAB direct databases. Of these, 171 records were excluded based on the screening of the titles and abstracts. Full texts of the remaining 17 articles were retrieved and three articles among these were excluded during further assessment for eligibility and quality. Of these 14 articles, 36% (5/14) was rated good and 64% (9/14) rated medium using the quality assessment criteria, with 14 of them being included in the qualitative synthesis (Figure 1).

3.2. Characteristics of the studies

Eighty-six percent (12/14) of the studies were conducted between 2010 and 2019, and the remaining two studies were between 2000 and 2009, with no earlier studies found. About 71% (10/14) of the studies covered Ouagadougou, the capital city. While samples were collected from different sampling points, 57% (8/14) of the studies had retail markets as, at least, one of their sampling points. About 86% (12/14), 21%(3/14) and 7%(1/14) of the studies investigated bacteria (Ilboudo et al., 2009; Kagambèga et al., 2011, 2018; Martikainen et al., 2012; Kagambèga et al., 2012a,b; Touwendsida et al., 2017; Somda et al., 2018; Waré et al., 2018; Cissé et al., 2019), fungi (Ssepuuya et al., 2018; Waré et al., 2018; Cissé et al., 2019) and parasites (Bamba et al., 2016), respectively. In addition to the food hazards, the studies also assessed hygiene indicator bacteria including *Enterobacterales* (Supplementary material S1) (Barro et al., 2002), aerobic mesophilic bacteria (Supplementary material S2) (Barro et al., 2002; Somda et al., 2018) and thermotolerant coliforms (Supplementary material S3) (Somda et al., 2018; Cissé et al., 2019). The number of articles that reported bacteria, fungi and parasite

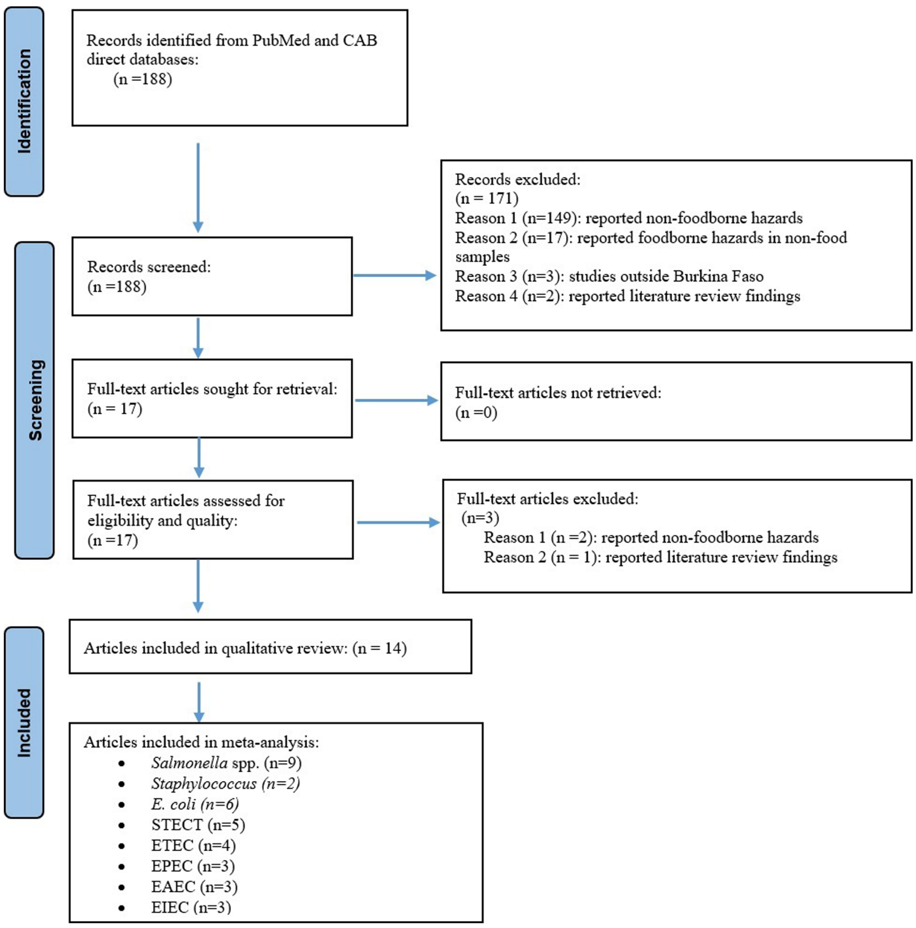

FIGURE 1
PRISMA flowchart showing abstract search, screening, and inclusion of eligible articles reporting foodborne hazards in Burkina Faso in the systematic review and meta-analysis, 1990–2019.

seem to exceed the number of articles included in the review when added up because some articles reported multiple hazards.

Studies included in this review assessed foodborne hazards in different food samples:

- Chicken samples (chicken meat, whole chicken carcass, grilled chicken, flamed chicken, fumed chicken, chickens prepared around fire);
- Cattle samples (beef, beef intestine);
- Sheep samples (fresh mutton, grilled mutton);
- Fish samples (fish);
- Pig samples (diaphragm, heart, fresh pork);
- Dairy products (raw milk, pasteurized milk, yoghurt, degue, Lait cailléc);
- Plant samples (maari-baobab seed fermented product);
- Vegetable and fruit samples (lettuce, Bissap, zoom-koom, Limburgui, fresh mango);
- Cereal and legume samples (sorghum, infant flours, boiled millet, rice sauce, fatty rice, cooked bean, peanut paste, terracotta peas); and.
- Water samples (tap water, channel water, reservoir water, well water).

In this article, we classified chicken samples as chicken meat while beef and mutton as meat. Of the samples mentioned above, chicken samples were most investigated (43% (6/14)) by the reviewed studies (Table 2).

3.3. Foodborne hazards in foods

3.3.1. *Salmonella* spp.

About 75% (9/14) of the articles reported *Salmonella* spp. in different food matrices with information on prevalence, serotypes and antimicrobial sensitivity of the serotypes (Barro et al., 2002; Ilboudo et al., 2009; Kagambèga et al., 2012a,b; Traoré et al., 2015; Kagambèga et al., 2018; Somda et al., 2018; Waré et al., 2018; Cissé et al., 2019). We included the nine *Salmonella* studies (1,201 samples) in meta-analysis to estimate its pooled prevalence. Although individual studies reported *Salmonella* prevalence ranging from 0–90%, the meta-analysis found an overall pooled prevalence of 13% (95% CI: 8–21). Chicken samples accounted for about 30.3% of the pooled *Salmonella* prevalence found in this meta-analysis. We observed substantial variation of *Salmonella* prevalence across the studies ($I^2 = 85$, 95% CI: 79–90%, $p < 0.01$). The subgroup analysis suggested that *Salmonella* prevalence varied by the sample types (Test for subgroup differences: $\chi^2_7 = 41$, df = 7, $p < 0.01$) (Figure 2).

3.3.2. *Campylobacter* spp.

Of the studies included in our review, one article (Kagambèga et al., 2018) reported *Campylobacter* spp. in poultry feces and carcasses collected from retail markets in Ouagadougou. The study showed that 68% (70/103) of fecal samples and 50% (10/20) of carcass samples were positive for *Campylobacter.*

3.3.3. Staphylococcus

Of the reviewed studies, three studies (Barro et al., 2002; Ilboudo et al., 2009; Cissé et al., 2019) reported *Staphylococcus* in chicken, meat, dairy products, fruits, cereals and legumes. The overall pooled microbial load of *Staphylococcus* in the studied food samples was 3.2 log (95% CI: 2.8–3.6) CFU per g or ml of food, with the highest microbial load being in chicken samples: 4.5 log (95% CI: 2.8–6.2) CFU per g or ml of food (Figure 3). Our meta-analysis revealed substantial variation of microbial load of *Staphylococcus* across the studies ($I^2 = 100\%$, $p < 0.01$).

3.3.4. *Escherichia coli*

About 43% (6/14) of the articles included in our review (Kagambèga et al., 2011, 2012a,b; Martikainen et al., 2012; Touwendsida et al., 2017; Somda et al., 2018) investigated *Escherichia coli* (*E. coli*) in beef intestines, meat (beef, mutton), chicken meat and dairy products with information on prevalence, pathotypes and antimicrobial sensitivity of the strains. We included these six studies reporting *E. coli* with 1,143 total samples in our meta-analysis. While individual studies reported an *E. coli* prevalence ranging from 0 to 100%, our meta-analysis showed an overall pooled prevalence of 40% (random-effects model, 95% CI: 29–51), with the highest prevalence being in beef intestines: 62% (95% CI: 22–91) and the lowest in dairy products: 31% (95% CI: 17–50). We observed substantial variation of *E. coli* prevalence across the studies ($I^2 = 86$, 95% CI: 80–90%, $p < 0.01$) (Figure 4). However, subgroup analysis of our meta-analysis showed weak evidence for variation of *E. coli* prevalence among sample types (Test for subgroup differences: $\chi^2_3 = 41$, df = 3, $p = 0.44$).

Studies included in this review also identified different pathotypes of *E. coli* including Shiga toxin-producing *E. coli* (STEC), enterotoxigenic *E. coli* (ETEC), enteropathogenic *E. coli* (EPEC), enteroinvasive *E. coli* (EIEC), and enteroaggregative *E. coli* (EAEC) (Martikainen et al., 2012; Kagambèga et al., 2012a,b; Somda et al., 2018). While STEC, ETEC, EPEC and EAEC were reported in meats, beef intestines, chicken meats and dairy products, EIEC was reported in chicken meat and dairy products. An overall pooled prevalence of STEC in the studied samples was 6% (95% CI: 3–11), highest in beet intestines: 25% (95% CI: 16–36) and lowest in dairy products: 0.6% (95% CI: 0.2–1.8) (Figure 5). We also found that pooled prevalence of ETEC, EPEC and EAEC were 3.3% (95% CI: 2.2–5.2) (Figure 6), 4.5% (95% CI: 1.7–11) (Figure 7) and 2% (95% CI: 1–4) (Figure 8), respectively. Reviewed studies also reported EIEC in chicken meat and dairy products with an overall contamination proportion of 1.1% (95% CI: 0.5–2.4) (Figure 9), higher in chicken meat: 2% (95% CI: 0.6–6.3).

3.3.5. Fungi

Waré et al. (2018) reported fungal spp. prevalences ranging from 3 to 70% in food samples with a pooled prevalence of 17.3% (95% CI: 1.6–73). They reported higher *Aspergillus* spp. prevalence (70% (95% CI: 63–76)) in infant flours than *Penicillium* spp. and *Fusarium* spp. Another study showed that 10% (95% CI: 7–14) of sorghum samples were contaminated with mycotoxins. This study also indicated that children below 6 years old in Burkina Faso have the highest mean consumption of sorghum per kg body weight in sub-Saharan African, implicating that they are a group at risk for mycotoxin exposure (Ssepuuya et al., 2018) (Figure 10).

3.3.6. Toxoplasma

Of the studies included in this review, one article reported a 29% (87/300) *Toxoplasma gondii* seropositivity in pig carcasses sampled

TABLE 2 Reviewed studies in the systematic review and meta-analysis of food hazards in Burkina Faso (1990–2019) with their study sites, sampling points, sample types and food hazards investigated.

Studies (references)	Study sites	Sampling points	Sample types	Food hazards
Cissé et al. (2019)	• Bobo Dioulasso • Djibo • Dori • Gorom-Gorom • Sebba	• Retail markets • Street vendors	• Cow milk • Camel milk • Goat milk	• *Salmonella* • *Staphylococcus* • *Shigella*
Kagambèga et al. (2018)	• Ouagadougou	• Retail markets	• Whole chicken carcass	• *Salmonella* • *Campylobacter* spp.
Somda et al. (2018)	• Ouagadougou	• Retail markets	• Grilled chicken • Flamed chicken • Fumed chickens • Chickens prepared around fire	• *Salmonella* • *E. coli*
Waré et al. (2018)	• Ouagadougou	• Recovery and nutrition education centres, • Semi-industrial units • Artisanal units	• Infant flours	• *Salmonella* • *Aspergillus* spp. • *Penicillium* spp. • *Fusarium* spp.
Ssepuuya et al. (2018)	• Burkina Faso (also in other sub-Saharan countries: Ethiopia, Mali, Sudan)	• Farmers (producers) • Retail markets • Consumers	• Grain sorghum	• Diacetoxyscirpenol • Deoxynivalenol • Aflatoxins • Fumonisins • Sterigmatocystin • Alternaria toxins • Ochratoxin A • Zearalenone
Touwendsida et al. (2017)	• Bobo-Dioulasso • Dori • Fada N'Gourma • Kongoussi • Sabcè • Léo • Ouahigouya	• Retail markets • Dairy farms • Dairy transformation units • Food shops • Supermarkets	• Raw milk • Pasteurized milk • Yoghurt • Degue (locally prepared fermented milk) • Lait caillé (locally prepared fermented milk)	• *E. coli*
Bamba et al. (2016)	• Bobo-Dioulasso	• Slaughterhouse	• Pork	• *Toxoplasma gondii*
Traoré et al. (2015)	• Ouagadougou	• Environmental samples	• Fish • Lettuce • Water samples (tap water, channel water, reservoir water, well water)	• *Salmonella*
Kagambèga et al. (2012a,b)	• Ouagadougou	• Retail markets	• Whole chicken carcass	• *Salmonella* • *E. coli*
Kagambèga et al. (2012a,b)	• Ouagadougou	• Retail markets	• Whole chicken carcass • Beef • Beef intestine • Mutton	• *E. coli*
Martikainen et al. (2012)	• Ouagadougou	• Retail markets	• Chicken samples • Beef • Beef intestine • Mutton	• *E. coli*
Kagambèga et al. (2011)	• Ouagadougou	• Retail markets	• Chicken samples • Beef • Beef intestine • Mutton	• *Salmonella* • *E. coli*

(Continued)

TABLE 2 (Continued)

Studies (references)	Study sites	Sampling points	Sample types	Food hazards
Ilboudo et al. (2009)	• Ouagadougou	• University cafeteria	• Raw meat • Meat-based cooked meals	• *Salmonella* • *Staphylococcus*
Barro et al. (2002)	• Ouagadougou	• Street vendors	• Street ready-to-eat foods made from cereals and legumes, vegetable and fruits, fresh pork, chicken meat	• *Salmonella* • *Staphylococcus* • *Shigella*

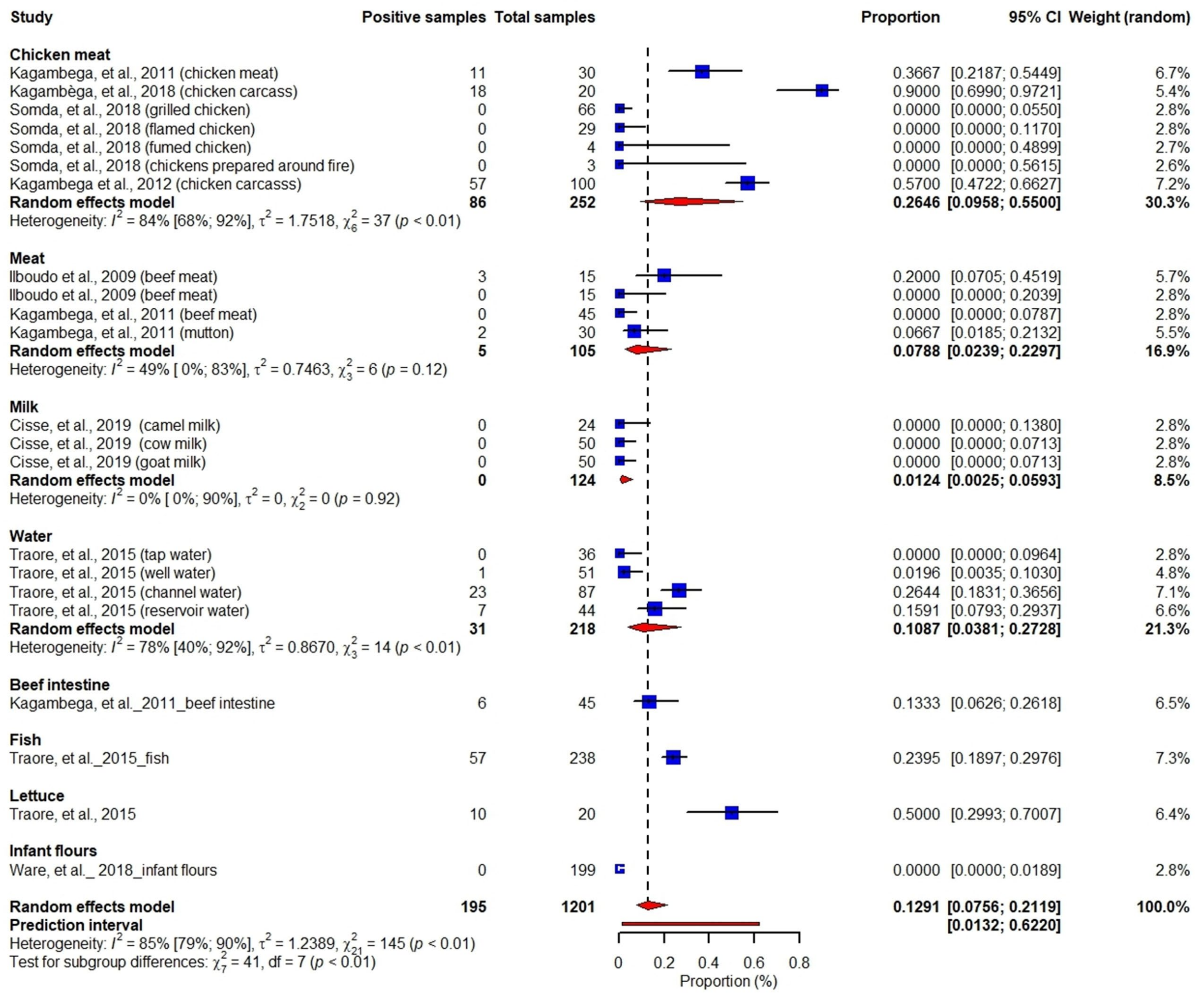

FIGURE 2
Forest plot showing prevalence of *Salmonella* in chicken meat, meat, milk, water, beef intestine, fish, lettuce and infant flours.

from slaughterhouse of Bobo-Dioulasso, the second largest city of Burkina Faso (Bamba et al., 2016).

4. Discussion

Our systematic review finding suggests increasing activities in food safety research in the country because we found a steady rise of the studies in food safety during the review period (1990–2019). However, most of these studies were conducted in the capital city of the country and assessed a small number of food hazards reflecting that the research is still inadequate in the country. Our review also implies widespread contamination of foods with different foodborne hazards including bacteria (*Salmonella*, *Campylobacter, Staphylococcus, E. coli*), fungi and parasites (*Toxoplasma gondii*), with bacteria the most studied hazard. In

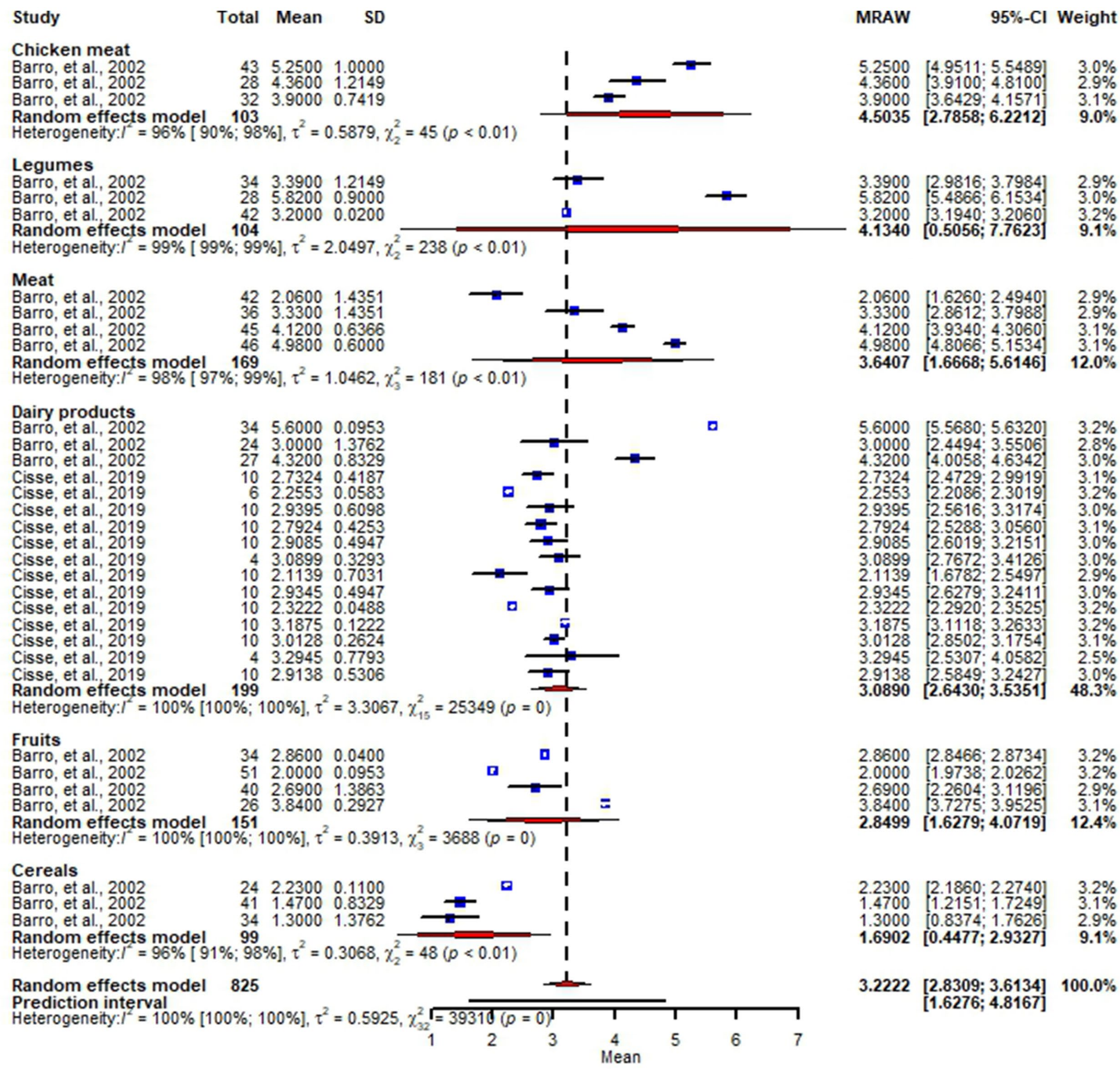

FIGURE 3
Forest plot showing microbial loads of *Staphylococcus* in chicken meat, legumes, meat, dairy products, fruits and cereals.

addition to the food hazards, the studies also investigated microbial loads of hygiene indicator bacteria such as *Enterobacterales,* aerobic mesophilic bacteria and thermotolerant coliforms in the food samples. Even if we reviewed and used the information of these hygiene indicator bacteria to support and interpret our findings on food hazards, we had not presented detail reports of these bacteria as the primary interest of this review was in foodborne hazards, but results are still reported as supplementary materials associated with this article (Supplementary materials S1–S3). The presence of these hygiene indicator bacteria in food samples suggests poor hygienic practices in food handling in Burkina Faso. Our review also indicated that foods have been contaminated with hazards along various food value chains such as beef, poultry, pork, fish, vegetables and crops, suggesting the extent of food safety problems in the country.

We found that most of the identified studies were conducted in the later decades of the review period (2010–2019), which indicates increasing efforts in food safety research. However, the sites of the studies were mostly geographically limited to the capital city of the country and only a few of the many foodborne hazards were assessed, showing that research remains inadequate. Furthermore, the studies investigated foodborne hazards in different food samples of chicken, cattle, sheep, fish, pig, dairy products, plants, vegetables and fruits, cereals and legumes, with most of the articles studying hazards in chicken meat. However, the studies often assessed bacteria, indicating limited focus on other foodborne hazards (although bacterial hazards are responsible for most of the foodborne disease burden). Consistent with our findings, food safety is often under-invested in Africa, especially in the dominant informal markets (GFSP, 2019). Food safety studies in Africa often have limited capacity-covering limited

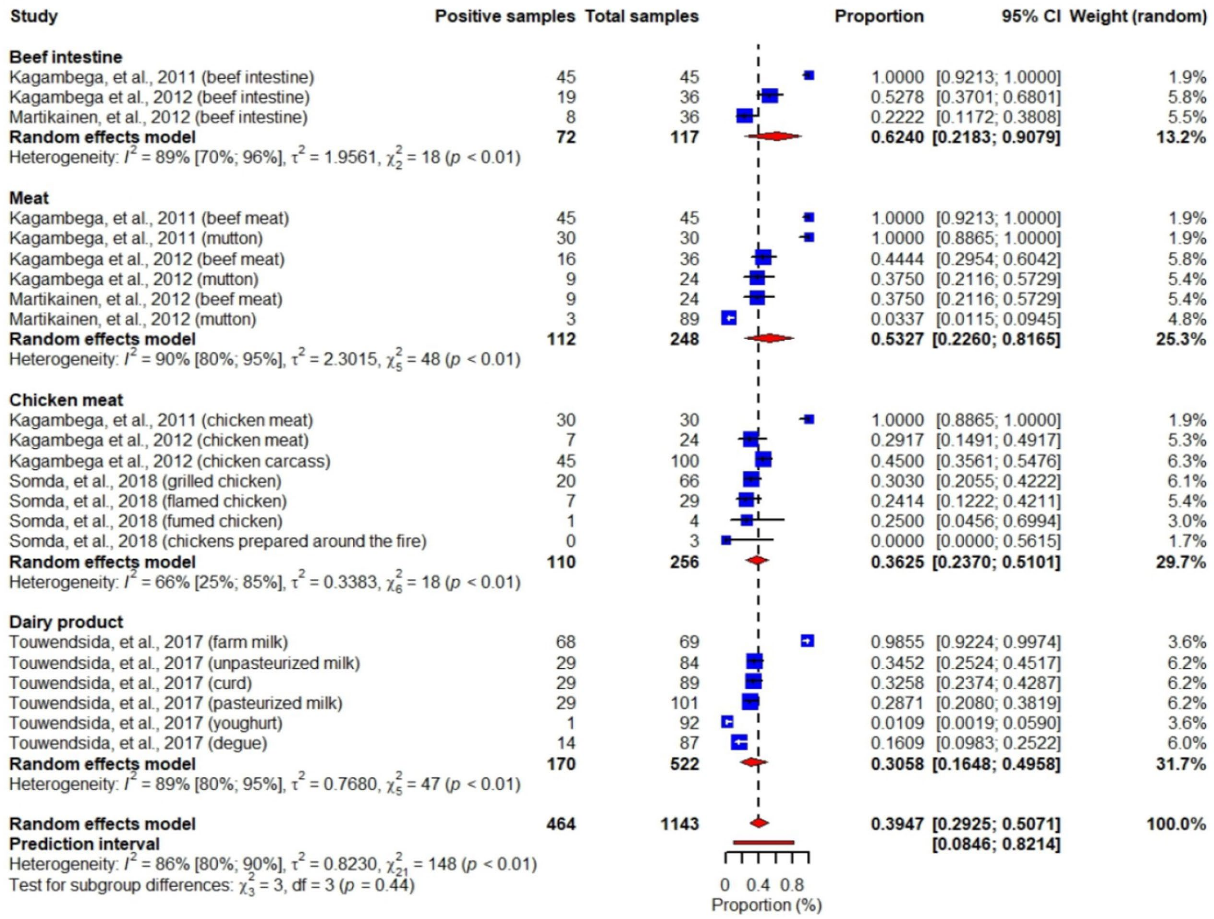

FIGURE 4
Forest plot showing *E. coli* prevalence in beef intestines, meats (beef, mutton), chicken meats and dairy products.

geographic areas of the study country and only a few foodborne hazards in their investigation scope (Paudyal et al., 2017).

Our present meta-analysis revealed contamination of chicken meat, meat, milk, water, beef intestine, fish, lettuce and infant flours with *Salmonella*, with higher pooled prevalence in chicken meats than meats and milk samples. Our review finding illustrated that meat products including-beef, mutton, chicken meat-appear to account for 44% of the pooled *Salmonella* prevalence reported in this review. Furthermore, subgroup analysis of our meta-analysis demonstrated that prevalence of S*almonella* could be significantly affected by sample types. *Salmonella* have often been isolated from the gastrointestinal tract of animals, but with varying colonization levels in different hosts (Ferrari et al., 2019; Thomas et al., 2020). Chickens are asymptomatic carriers of *Salmonella*, leading to cross-contamination of the carcass during or after slaughtering, causing higher prevalence in poultry products (Dione et al., 2009). Poultry is the most common source of foodborne salmonellosis in the United States of America, with chicken, turkey and egg products attributing to nearly seven out of ten human cases (Thomas et al., 2020). Higher *Salmonella* prevalence in foods has been reported in Africa (Paudyal et al., 2017), with poultry in Africa having a higher prevalence of *Salmonella* than other food animals (Thomas et al., 2020). One study found that *Salmonella* were significantly more likely to be isolated or detected from western (including Burkina Faso) and central African food animal samples than samples from northern Africa (Thomas et al., 2020).

One paper reported *Campylobacter* spp. in chicken carcass, with 50% of the carcass samples being positive for the bacteria. However, relatively lower prevalence of *Campylobacter* in chicken meat was reported in different developing countries: 32.8% in Benin (Kouglenou et al., 2020), 38.8% in Ghana (Asuming-Bediako et al., 2022) and 26.6% in Malaysia (Sinulingga et al., 2020). Variation in *Campylobacter* prevalence could be due to animal species, season of the study and sample types (Ozbey and Tasdemir, 2014; Thomas et al., 2020).

Studies in this review found *Staphylococcus* in food products made from chicken meat, meat, dairy products, fruits, cereals and legumes, with an overall pooled bacterial load of 3.2 log (95% CI: 2.8–3.6) CFU per ml or g of food, highest load being in chicken samples: 4.5 log (95% CI: 2.8–6.2) cfu per ml or g of food. Buzon-Duran, et al. found a slightly higher bacterial loads of *Staphylococcus* in poultry meat, 4.07 ± 0.80 log10 cfu/g and Tsehayneh et al. (2021) reported comparable *Staphylococcus* bacterial loads in Ethiopia in raw meat from butcher shops, 3.40 ± 0.63 (log10 cfu/g). In general, the bacterial load counts requirement for *Staphylococcus* in food products should be below 20 cfu/g (Health Protection Agency, 2009), reflecting that

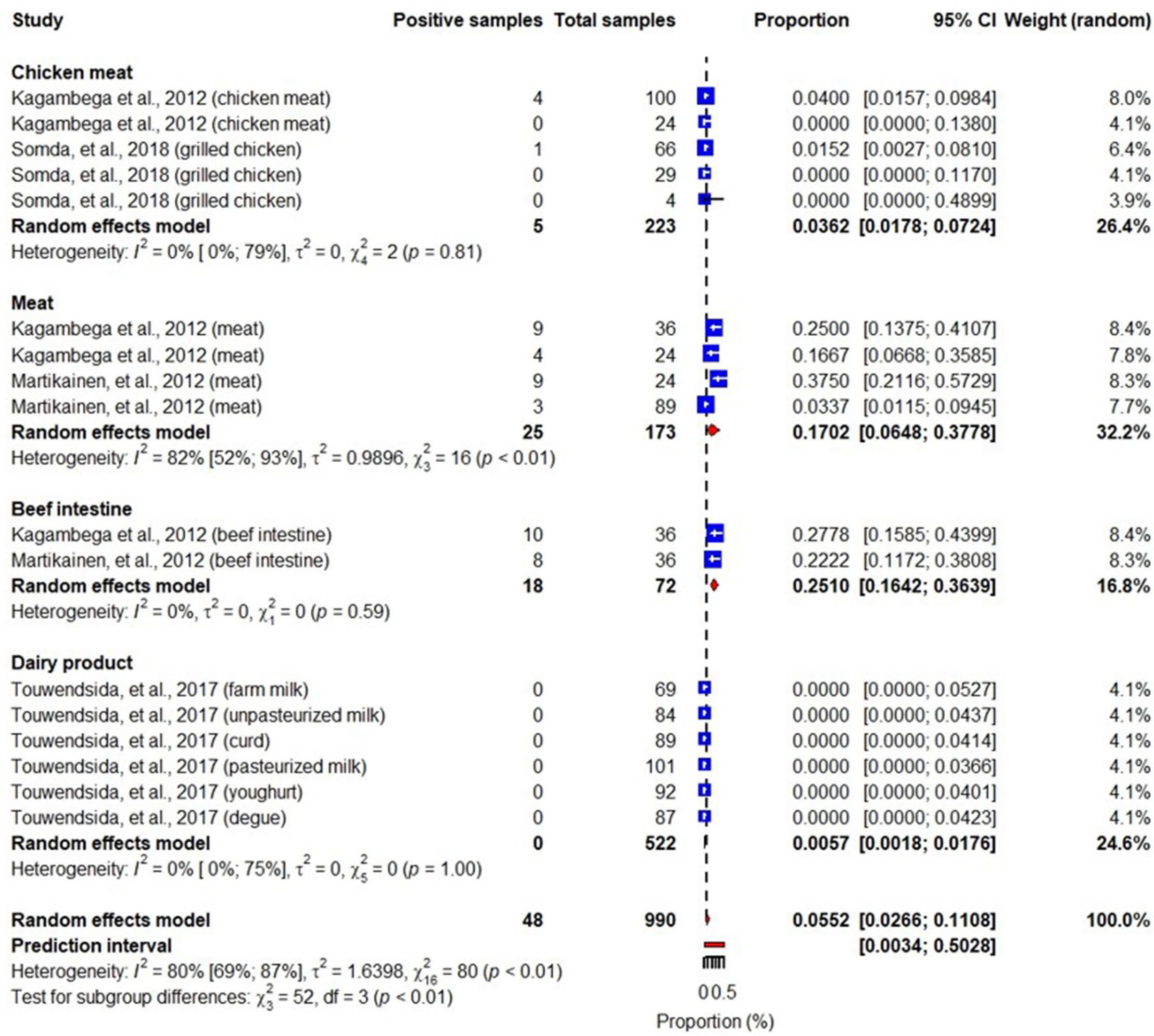

FIGURE 5
Forest plot showing STEC prevalence in meats, beef intestines, chicken meats and dairy products.

finding of this meta-analysis demonstrated an exceedance of the maximum microbiological limit of the hazard in foods for human consumption.

This systematic review demonstrated presence of *E. coli* in beef intestines, meat (beef, mutton), chicken meat and dairy products, with the highest prevalence in beef intestines and the lowest in dairy products. Our research found a 40% overall pooled prevalence of *E. coli* in the studied food products. Previous studies reported comparable *E. coli* overall prevalence values in foods, such as 35% in Africa (Paudyal et al., 2017) and 34% in developing countries (Mengistu and Tolera, 2020). However, other studies reported lower prevalence values, such as 15% in Ethiopia (Assefa and Bihon, 2018) and 4% in China (Paudyal et al., 2018). Differences could be due to variations in food products as, for example, in our meta-analysis we found that while meat products (beef, beef intestines, mutton, chicken meat) accounted for about 70% of *E. coli* pooled prevalence, the rest was contributed by dairy products. However, sub-group analysis of *E. coli* prevalence in the present meta-analysis indicated that sample types have weak effects on *E. coli* prevalence. Although *E. coli* is a common inhabitant of gastrointestinal tract of animals and humans and not all strains are pathogenic, some *E. coli* are pathogenic capable of causing illness in humans such as diarrhea or illness outside of the intestinal tract (Levine, 1987; Kaper et al., 2004). Five out of the six diarrheagenic *E. coli* pathotypes including STEC, EPEC, ETEC, EIEC, and EAEC were reported by the reviewed studies included in the recent review. In addition, a previous study has illustrated that an estimated burden of ETEC associated with beef, dairy, poultry meat, and vegetables was found increasing in Burkina Faso from 2010 to 2017 (Havelaar et al., 2022). The presence of *E. coli* in foods is an indicator of both poor hygienic handling practices of foods and of presence of other fecal pathogens in foods (Health Protection Agency, 2009). Food can become contaminated

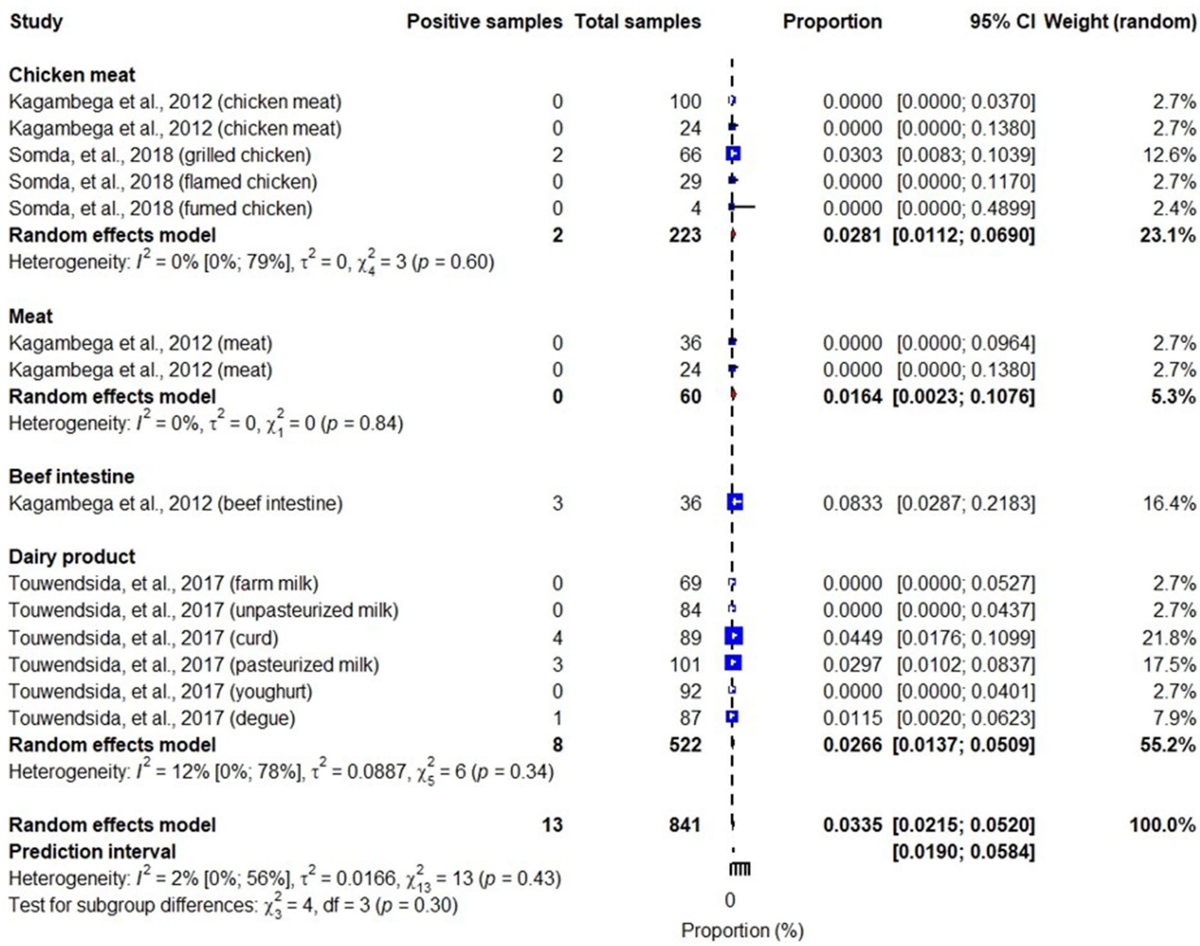

FIGURE 6
Forest plot showing ETEC prevalence in meats, beef intestines, chicken meats and dairy products.

with *E. coli* at all stages of food production and retail. Evisceration during slaughtering and defecation during milking are critical events where *E. coli* are likely to enter food products destined for human consumption (Hussein, 2007).

Several factors seem to contribute to the higher contamination levels of studied food samples with the identified food hazards in Burkina Faso. Poultry is one of the main asymptomatic carriers of *Campylobacter* and *Salmonella* (Thomas et al., 2020), which might cause the higher contamination level of chicken samples with these hazards especially during slaughtering due to carcass cross-contamination. Studies in Burkina Faso have provided evidence that chicken retailers slaughter chickens in a traditional way-they themselves slaughter chickens in marketplaces, executing bleeding, plucking, evisceration, and cutting on the same table; rinse carcasses in the same bucket of water and sold off a table at ambient temperature without any type of protection from dust and pests at any point during the day. Moreover, poultry vaccinations are not mandatory in the country which leads to higher pathogen prevalence in the poultry population, causing higher carcass cross-contamination during slaughtering (Kagambèga et al., 2018). Food retailers in Burkina Faso have inadequate safe food handling knowledge and practices (Barro et al., 2002; Ilboudo et al., 2009; Kagambèga et al., 2018). Furthermore, we found, in our meta-analysis, higher microbial loads of hygiene indicator bacteria including *Enterobacterales*, aerobic mesophilic bacteria and thermotolerant coliforms in different food commodities representing poor hygienic practices related to food handling (Health Protection Agency, 2009), which might contribute to the higher contamination of studied food commodities with the hazards in the country.

One of the unique strengths of this systematic review is its ability to do a meta-analysis, providing pooled contamination levels of the hazards in the studied food samples. To the best of our knowledge, this is the first systematic review of foodborne hazards in Burkina Faso using a meta-analysis. A meta-analysis generates pooled estimate results through combining individual studies' results which is more informative compared to narrative reviews' findings. Such pooled estimates from a meta-analysis would enable informed policy-and decision-making (Van Wely, 2014).

However, this review was subjected to two main limitations. First, high heterogeneity was observed among some studies included in this meta-analysis, although, combining studies with low heterogeneity is recommended to be sure that the studies' findings are comparable. However, as systematic reviews synthesize results from studies that are diverse in different aspects such as sampling techniques, laboratory methods, sample size and so on, it is almost

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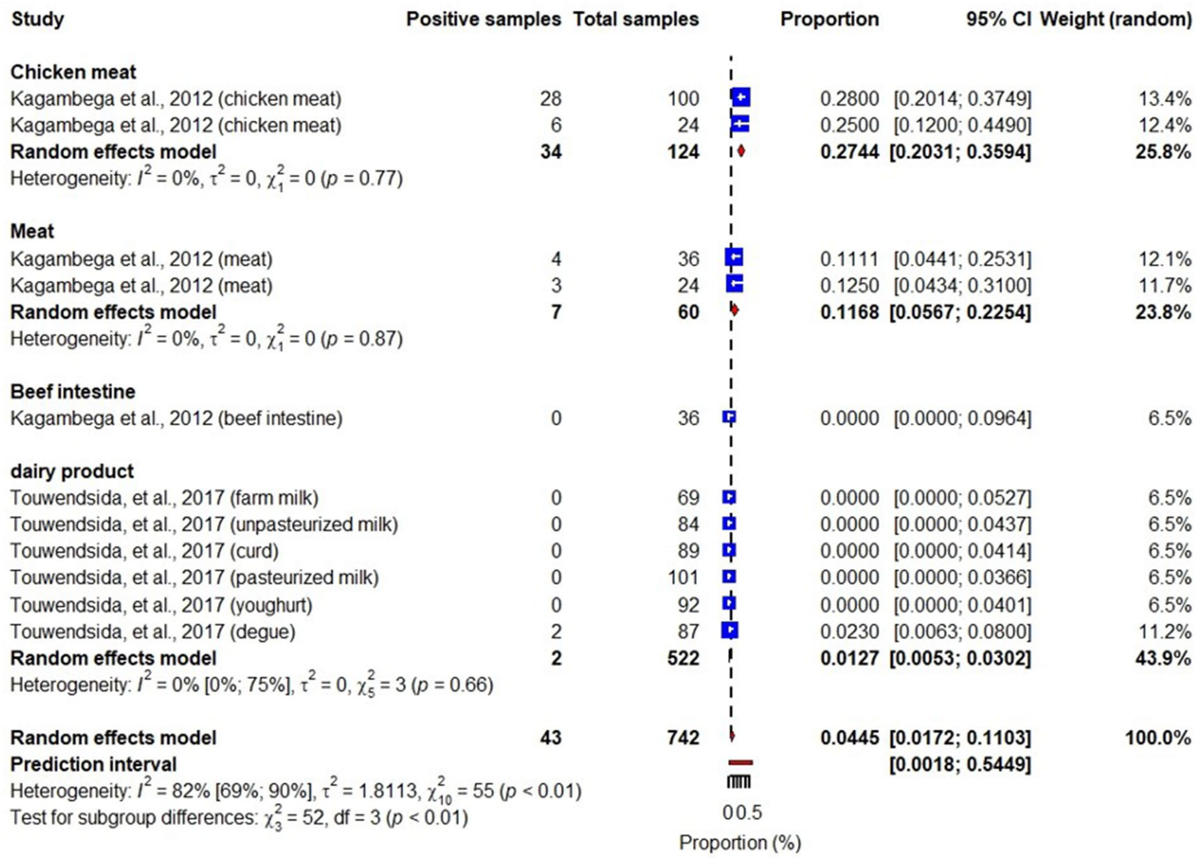

FIGURE 7
Forest plot showing EPEC prevalence in meats, beef intestines, chicken meats and dairy products.

inevitable to see some heterogeneity across the studies (Higgins et al., 2002). We conducted subgroup analysis by categorizing food products that share common characteristics such as meat, chicken meat, intestines, dairy product and so on to understand the sources of heterogeneity. We found that the prevalence of some hazards such as *Salmonella* could be affected by sample types, reflecting that even if studies are comparable in many ways heterogeneity could arise from the sample types investigated. Strict inclusion and exclusion criteria were also used to include only relevant studies in the review. Second, results of few studies were combined in the recent meta-analysis, for example, only two studies were used in the meta-analysis of *Staphylococcus*. Although results from two primary studies can be combined in a meta-analysis, combining findings of more studies would improve the quality of meta-analysis findings. It is therefore recommended to cautiously interpret the findings based on the limitations.

Our review found more food safety studies in recent years, indicating growing awareness of this problem. However, many important hazards receive little research attention and there is sparse information on food hazards outside the capital of Burkina Faso. In addition, most studies were at the retail point and there was a lack of information from other important nodes of the food value chains (e.g., production, processing, consumption).

Our review findings also demonstrated high prevalence of contamination of foods with hazards, including *Salmonella* spp., *Campylobacter* spp., *Staphylococcus* spp., toxigenic *E. coli,* fungi and *Toxoplasma gondii.* The presence of hygiene indicator bacteria such as *Enterobacterales,* aerobic mesophilic bacteria and thermotolerant coliforms in foods is indicative of poor hygiene practices while handling foods. These may include undercooking, cross contamination from raw food especially meat, food handlers or food contact surfaces as well as poor temperature and time control. Our findings indicated that a variety of food samples were reported contaminated with food hazards reflecting the need to target different food value chains- including beef, poultry, pork, vegetables, cereals, fruits and water-for food safety interventions. Consistent with our findings, a review on food hazards in Ethiopia showed that food contamination with hazards is common in beef, poultry and vegetable food value chains (Gazu et al., 2023). The widespread contamination of foods with hazards in the country raises public health concerns, especially for vulnerable groups such as children, the elderly, pregnant women and the immunocompromised.

Our results suggest that interventions are urgently needed to improve the safety of food retailed in the capital city of the country. More information is needed on food safety in outside of the capital city of the country; in different food value chains; at the different points along the food value chains and on a variety of food hazards. We suggested food safety interventions targeting different food value chains, and improved monitoring of hazards in food in the country.

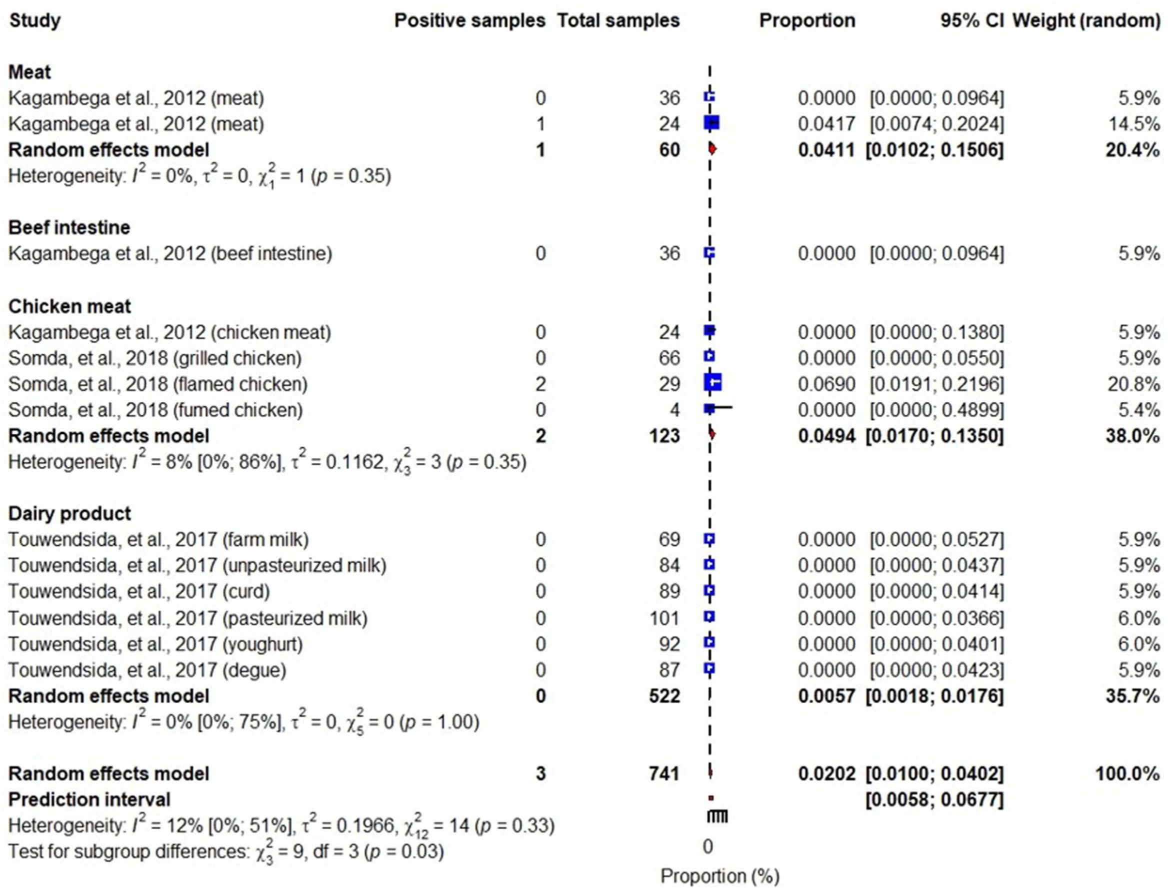

FIGURE 8
Forest plot showing EAEC prevalence in meat, beef intestines, chicken meat and dairy products.

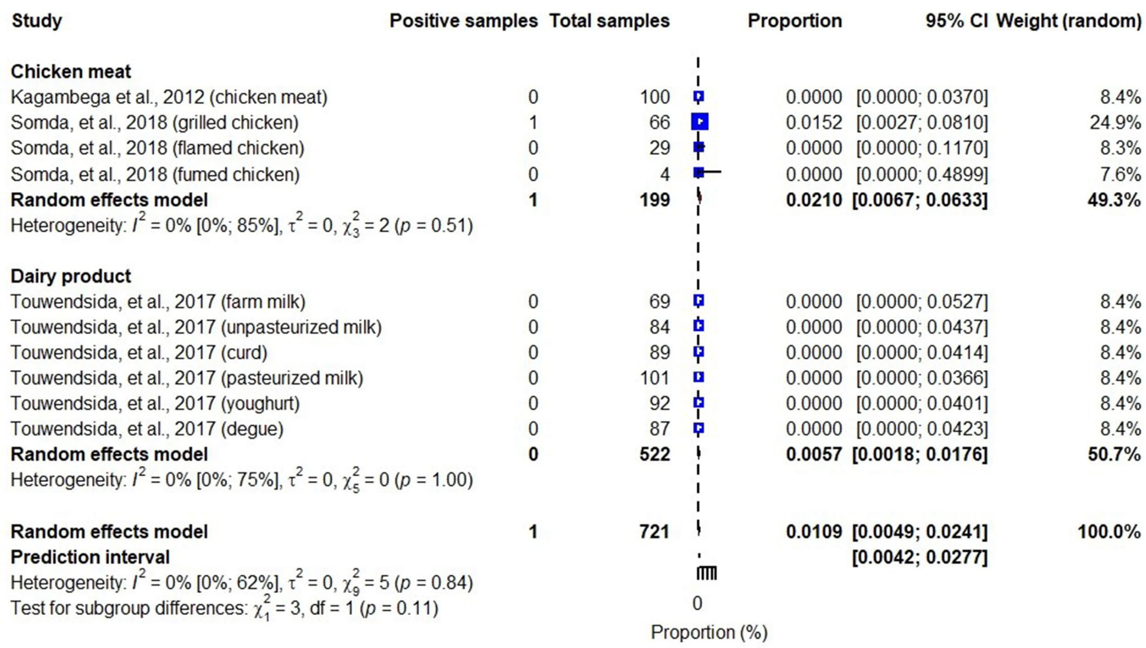

FIGURE 9
Forest plot showing EIEC prevalence in chicken meats and dairy products.

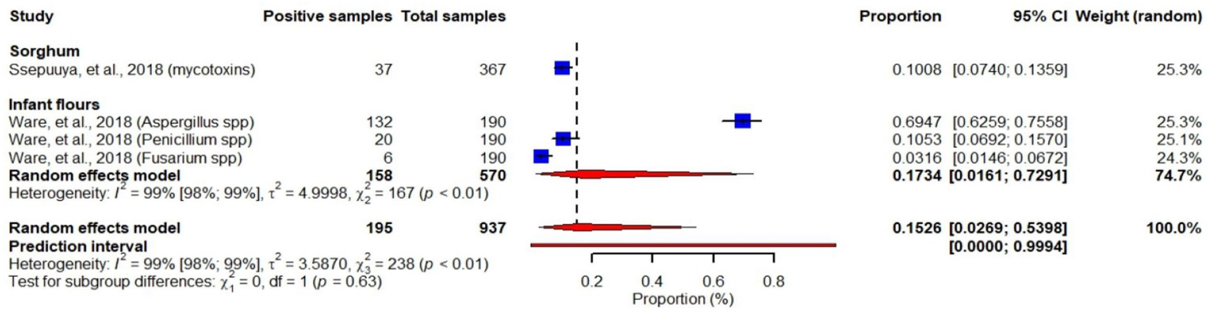

FIGURE 10
Forest plot showing prevalence of fungi and mycotoxins in infant flours and sorghum. Forest plot was just used to visualize the proportions as reported in the individual studies and the overall pooled prevalence was not considered in our report since mycotoxins reported by Ssepuuya et al. (2018) and fungal species reported by Waré et al. (2018) are not comparable.

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

DG conceived, designed, supervised and managed the project and received funding for the study. SA, KA, and LG searched and screened abstracts, retrieved eligible studies. GD assessed relevant studies quality, extracted data, conducted meta-analysis and wrote original draft of the manuscript. TK-J, SA, KA, LG, FM, KR, JL, FS, PU, TG, GI, and DG reviewed and edited the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This work was supported by the Bill & Melinda Gates Foundation [INV-008430 (OPP1195588)]. Under the grant conditions of the Bill & Melinda Gates Foundation, a Creative Commons Attribution 4.0 Generic License has already been assigned to the Author Accepted Manuscript version that might arise from this submission. The work was also supported by the German Federal Ministry for Economic Cooperation and Development (BMZ) through the One Health Research, Education and Outreach Centre in Africa (OHRECA) led by ILRI. Additional support was received from CGIAR Research Program on Agriculture for Nutrition and Health (A4NH). Support was also provided by UK aid from the UK Foreign, Commonwealth and Development Office.

Acknowledgments

This activity is part of the urban food markets in Africa: incentivizing food safety using a pull-push approach which is supported by the Bill & Melinda Gates Foundation, German Federal Ministry for Economic Cooperation and Development (BMZ) through the One Health Research, Education and Outreach Centre in Africa (OHRECA) led by ILRI, the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH) led by the International Food Policy Research Institute and the Foreign, Commonwealth and Development Office (FCDO) of the UK Government. We also acknowledge the CGIAR Fund Donors (https://www.cgiar.org/funders).

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.2023.1232992/full#supplementary-material

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