Foodborne Microbiological Hazards in Ghana: A Scoping Review

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ABSTRACT

BACKGROUND: Foodborne diseases pose a significant public health threat, particularly in regions with poor sanitation and food handling practices. These diseases, mainly caused by microbiological hazards like bacteria, fungi, and parasites, affect millions globally. Despite the global burden, the true extent of these hazards remains underestimated, especially in low- and middle-income countries like Ghana. This study aimed to map the available literature on foodborne microbiological hazards in Ghana, providing an overview of the evidence and identifying areas where further research is needed.

METHOD: This review followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis Extension for Scoping Reviews. A detailed search was done in PubMed, Scopus, Web of Science, and Google Scholar, and articles were exported to Rayyan for screening. A three-phase screening process was used to identify relevant articles. Data from the included articles were extracted and analysed, with specific information related to food type, specific hazards, sample population, and hazard groups summarised using proportions and tables.

RESULTS: This review included 72 studies which were published between 2001 and 2023. Eighty-five percent of these studies (85%) reported on bacterial hazards, while 19%, 11%, and 6% reported on fungi, parasites, and mycotoxins, respectively. The most reported bacterial, fungal, and parasitic hazards were *Escherichia coli*, *Aspergillus* spp. and *Trichuris trichiura*, respectively. Aflatoxins were reported in maize, groundnut, and spices, with prevalence ranging from 61% to 100% and at levels exceeding standards set by Ghana Standards Authority and European Food Safety Authority.

CONCLUSION: This review highlighted the spectrum of microbiological hazards in foods in Ghana. The hazards identified pose significant public health risks, particularly among vulnerable populations. It is crucial that stricter enforcement of food safety laws and improved food handling practices are implemented in the country, particularly in the informal food sector, to protect consumers.

KEYWORDS: Food microbiology, food safety, foodborne pathogens, foodborne microbes

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Introduction

Foodborne diseases, which result from foodborne hazards, pose a significant public health threat, particularly in regions where high prevalence of sanitation lapses and poor food handling practices exist.[1,2] These foodborne hazards, typically categorised as biological, chemical, and physical, are extensively distributed globally, and dictate the spectrum of foodborne ailments and conditions.[3] Biological hazards, which include pathogenic organisms (spanning across viruses, bacteria, parasites, and fungi) and their associated toxins, constitute the predominantly implicated hazard in about 97% of foodborne illness outbreaks and cases worldwide.[4,5]

Globally, millions of foodborne disease cases occur every year, with reports indicating that the burden is comparable to those of major infectious diseases like HIV/AIDS, malaria, and tuberculosis.[4,6] According to a recent global estimate by the World Health Organization (WHO), 600 million cases of foodborne illnesses caused by over 30 foodborne hazards are reported each year, resulting in approximately 420,000 deaths.[4,7] Notably, Africa bears the highest burden of these foodborne diseases with an estimated 1200-1300 disability-adjusted life years (DALYs) per 100,000 people compared to 35–71 DALYs in other regions.[8] However, the true extent of the health burden associated with foodborne hazards and diseases (such as morbidity and mortality) remains largely unknown, especially in low- and middle-income countries where the burden is frequently underestimated.[8]

In Ghana, there is an immense public health risk posed by foodborne diseases. A report by the country's Ministry of Food and Agriculture and the World Bank noted that on an annual basis, approximately one (1) in every forty (40) individuals (an estimated 420,000 persons) suffers from foodborne illnesses, approximately 65,000 of whom lose their lives.[9] Despite the presence of regulatory bodies in Ghana, there appears to be a problem with adherence to food safety standards within the food industry, particularly in the informal sector, and hence the high risk posed by foodborne hazards.[10]

It is crucial to gather and consolidate information on foodborne hazards within a country and identify specific foods that are mostly contaminated by these hazards in order to effectively prioritise food safety policies and allocate resources to areas with the greatest food safety risk.[11] Such studies have been conducted in a number of African countries to aggregate information on microbial contamination in food, enabling evidence-based policies and decision making by various stakeholders.[12-16] In Ghana, previous reviews on the microbial safety of food are limited in scope and are now outdated. Notably, the review conducted by Saba & Gonzalez-Zorn[17] over a decade ago reported on a limited number of microbiological hazards, failing to account for fungi, parasites, and other clinically-significant foodborne bacterial pathogens, such as *Listeria monocytogenes*, *Clostridium perfringens*, and *Escherichia coli* O157:H7. This review provided findings based on a limited number of studies (11 articles),[17] resulting in a restricted perspective of the evolving landscape of food safety research in Ghana. Additionally, the review by Yeleliere et al.[18] was narrative and focused on select cities, and thus, may not provide a comprehensive overview of the food safety situation in the country. Besides, there has been a significant increase in research outputs on the theme over the years. Synthesising the wealth of contemporary knowledge on this topic is, therefore, warranted to yield a more accurate and up-to-date understanding of the microbiological hazards present in foods in Ghana. The objective of this study was to systematically map the available literature on foodborne microbiological hazards in Ghana, providing an overview of the evidence and also identifying areas where further research is needed.

Methodology

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR).[19] The primary focus of this review was on peer reviewed-literature; hence no gray literature sources were searched.

Study design and search strategy

Original articles were sourced from different databases, namely PubMed, Web of Science, Scopus, and Google Scholar, to reduce biases.[20,21] The literature search for this study was conducted between December 7 and 11, 2023, and March 1 and 5, 2024. The search terms, as presented in Table 1, were used to search the databases and the results were exported into Rayyan for screening.[22] For Google Scholar, only the first 400 results were collected. The search was specifically limited to peer-reviewed articles published in the English language by December 2023. A total of 1708 results were retrieved for screening.

Table 1. Databases, search terms, and results retrieved.

DATABASE (*N* = RESULTS RETRIEVED)	SEARCH TERMS
PubMed (*n* = 429)	"Food Microbiology"[Mesh] OR "Food Contamination"[Mesh] OR "Foodborne Diseases"[Mesh] OR "Food Safety"[Mesh] OR "food quality" OR "food* hazards" OR "food* bacteria" OR "food* virus" OR "food* parasit*" OR "food* fungi" OR "food* outbreak" OR "food hygiene" OR "food contamina*" OR "food* pathogen" OR "food* toxins" OR "food* poison*" OR "food microb*" AND Ghana.
Scopus (*n* = 378) Web of Science (*n* = 501)	(ALL = ("Food Microbiology" OR "Food Contamination" OR "Foodborne Diseases" OR "Food Safety" OR "food quality" OR "food* hazards" OR "food* bacteria" OR "food* virus" OR "food* parasit*" OR "food* fungi" OR "food* outbreak" OR "food hygiene" OR "food contamina*" OR "food* pathogen" OR "food* toxins" OR "food* poison*" OR "food* microb*")) AND ALL = (Ghana)

Eligibility criteria

Original articles were required to meet at least one of these requirements in order to be included in the study: (i) reported specific microbiological hazards in foods in Ghana and (ii) reported on the prevalence and/or microbial load of these hazards in foods in Ghana. Studies that exclusively investigated microbiological hazards that are unrelated to foodborne diseases were excluded from the analysis. Those that reported microbiological hazards solely in non-food items, such as animal faeces, packaging materials, and food processors, were also excluded.

Study selection

A three-phase screening process was used to retrieve articles of interest for the review. In the first screening phase, duplicates were removed manually using the Rayyan Systematic Review (RSR) platform.[22] Titles and abstracts of the retained articles were screened and assessed for eligibility using the RSR platform in the second screening phase. In the final screening phase, the full-text articles were thoroughly read to include relevant articles based on the objectives of the study. A set of criteria was employed to evaluate the quality of full-text articles, encompassing the utilisation of scientifically rigorous methods, appropriate laboratory procedures, and precise reporting of results. Figure 1 below shows the process of article selection.

Data extraction and analysis

Data from each included article was extracted and recorded in an Excel spreadsheet, categorised by author(s), year of publication, study sites, sampling points, food type, specific

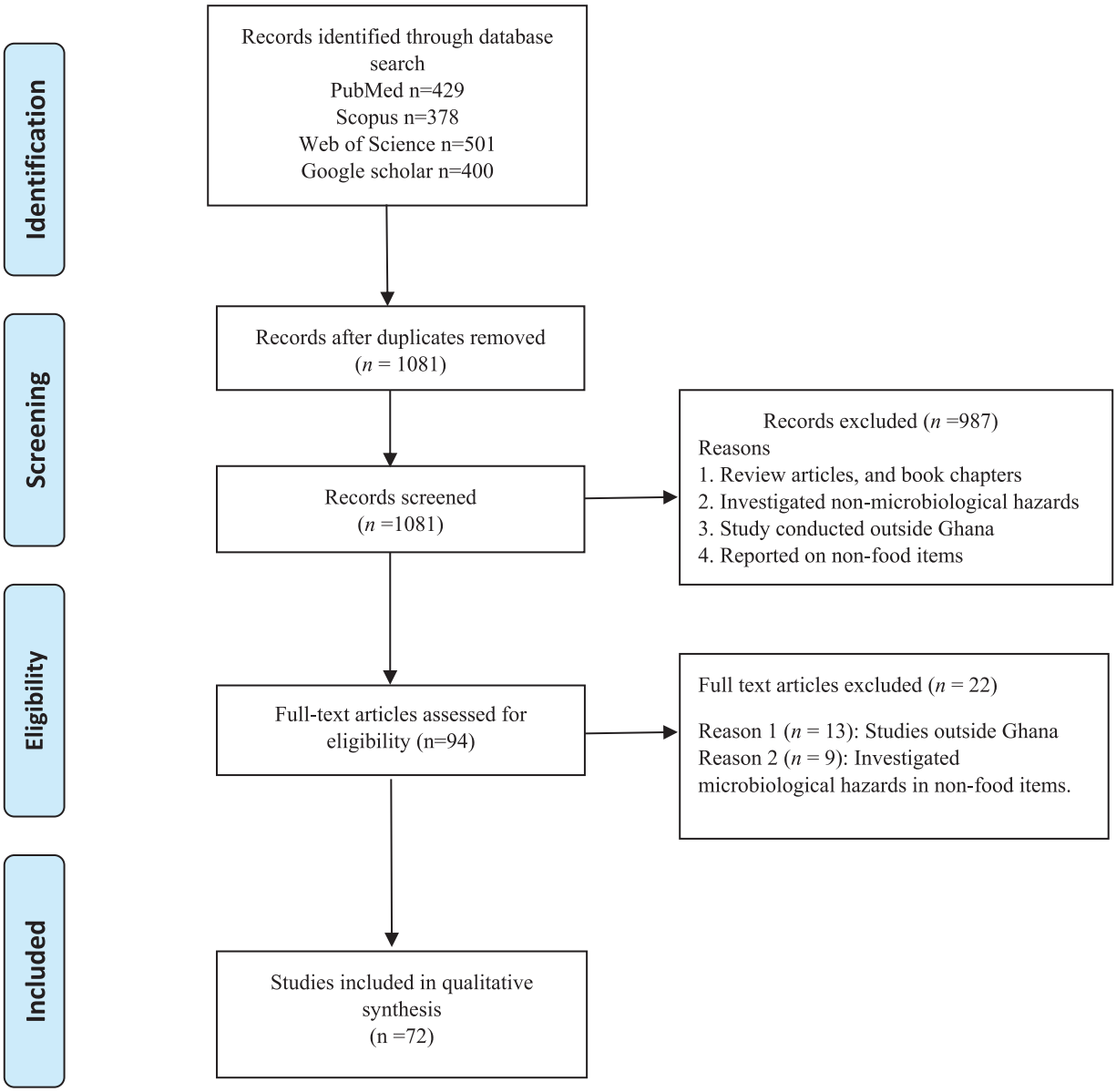

Figure 1. PRISMA flow diagram providing a visual representation of the article selection process of this scoping review.

microbiological hazards, and hazard groups. The extracted data were then analysed and summarised as proportions. A narrative description of the included articles was presented, along with an analysis of the number and geographic distribution of the articles. The results and conclusions obtained were thematically combined and presented in tables and figures, to provide a visual representation of the findings.

Results

Following the completion of all screening processes, a total of 72 articles were selected for inclusion in this scoping review (Table 2).

Characteristics of the studies

This review comprised a total of 72 articles of which 82% (59/72) were conducted between 2012 and 2023, and the remaining 18% (13/72) were conducted between 2001 and 2011. In terms of study locations, the majority of the studies (44%, 32/72) were conducted in Accra, which is the capital city of Ghana. The remaining studies were conducted in Kumasi (17%, 12/72), Tamale (15%, 11/72), Bolgatanga (6%, 4/72), Cape Coast (6%, 4/72), Koforidua (3%, 2/72), Ho (3%, 2/72), and Yeji (1%, 1/72). Four (4) studies, representing 6%, were conducted across several regions in Ghana. Most of the studies (85%, 61/72) reported on bacterial hazards; 19% (14/72) reported on fungi; 11% (8/72) investigated parasites. Four articles (6%, 4/72) reported on mycotoxins, specifically aflatoxin and fumonisins. It is worth noting that the total count of articles reporting on bacteria, fungi, parasites, and mycotoxin exceeded the number of articles included in the review as certain articles addressed multiple hazards concurrently.

Table 2. Included studies in the systematic review of foodborne hazards in Ghana with study sites, sampling points, sample types, food hazards, and hazard group.

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Abakari et al.[23]	2019	Tamale (Northern Region)	Food joints	Soup (Ayoyo and dry okra)	*Escherichia coli* *Salmonella* spp. *Shigella* spp. *Staphylococcus aureus*	Bacterial
Abakari et al.[24]	2018	Tamale (Northern Region)	Street food vendors	Vegetable Salad	*Escherichia coli* *Bacillus cereus* *Shigella* spp. *Salmonella* spp.	Bacterial
Abas et al.[25]	2019	Tamale (Northern Region)	Retail markets	"Tuo-Zaafi"	*Escherichia coli* *Shigella* spp. *Salmonella* spp. *Staphylococcus aureus*	Bacterial
Abass et al.[26]	2016	Kumasi (Ashanti Region)	Vegetable farms	Lettuce Spring onions Cabbage	*Escherichia coli* Total coliforms Faecal coliforms	Bacterial
Aboagye et al.[27]	2020	Kpong James Town (Greater Accra Region)	Fish farmers Fish processors	Tilapia African catfish Sardinella artisanal	*Aeromonas sobria* *Listeria* spp. *Proteus* spp. *Staphylococcus aureus* *Klebsiella* spp. *Pseudomonas* spp. *Escherichia coli* *Clostridium perfringens*	Bacterial
Aboagye et al.[28]	2020	Accra (Greater Accra Region)	Cafeteria	Asaana *Hibiscus sabdariffa* calyxes extract (sobolo)	*Staphylococcus aureus* *Escherichia coli* *Salmonella* spp. *Shigella* spp. *Bacillus* spp. *Streptococcus* spp. *Aspergillus fumigatus* *Aspergillus flavus* *Aspergillus ustus* *Aspergillus niger* *Aspergillus ochraceus* *Fuserium* spp. *Fuserium. oxysporum* *Fuserium. avenaceus* *Carvulania lunata* *Fuserium. citrinum* *Fuserium. verticilliodes* *Penicillium digitatum* *Rhodotorula* spp. *Penicilium citrinum*	Bacterial Fungal
Adu-Gyamfi et al.[29]	2012	Accra (Greater Accra Region)	Supermarkets Local markets Farms	Raw chicken	*Salmonella* spp. *Staphylococcus aureus* *Escherichia coli*	Bacterial
Abubakari et al.[30]	2015	Kumasi (Ashanti Region)	Restaurants Cafeterias Street food	Ready-to-eat salad	*Escherichia coli* *E. coli* 0157:H7	Bacterial
Addo et al.[31]	2015	Accra (Greater Accra Region)	Abattoirs	Raw beef	*Escherichia coli* *Staphylococcus aureus* *Salmonella typhirium* *Listeria monocytogenes* *Yersinia. enterocolitica* *Enterobacter* spp. *Bacillus* spp. *Aeromonas* spp. *Pseudomonas* spp. *Klebsiella* spp.	Bacterial

(Continued)

Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Addo et al.[32]	2011	Coastal Savannah Zone	Dairy farms	Raw cow milk "Wagashi" "Burchina" Yoghurt	*Escherichia. coli*	Bacterial
Adjei et al.[33]	2022	Ashaiman (Greater Accra Region)	Slaughter slab Retail outlet	Raw beef	*Escherichia coli* *Staphylococcus aureus* *Klebsiella pneumoniae* *Streptococcus* spp. *Citrobacter* spp. *Pseudomonas aeruginosa* *Proteus* spp. *Bacillus* spp. *Enterococcus faecalis* *Enterobacter cloacae*	Bacterial
Adu-Gyamfi[34]	2006	Madina Kaneshie Dome Mallamatta (Greater Accra Region)	Smokehouses Markets Canteens	Smoked tuna Smoked mackerel	*Escherichia coli* *Enterobacter cloacae* *Enterobacter sakazakii* *Enterobacter amnigena* *Enterobacter aerogenes* *Erwinia spp.* *Klebsiella pneumoniae* *Proteus mirabilis* *Serrata plymuthica* *Geotrichum* spp. *Paecilomyces* spp. *Aspergillus niger* *Aspergillus versicolor* *Aspergillus wentii* *Penicillium* spp. *Rhizopus* spp.	Bacterial Fungal
Adzitey et al.[35]	2010	Tamale (Northern Region)	Meat retail points	Chevon Mutton	*Staphylococcus* spp. *Salmonella* spp. *Escherichia coli* *Enterococcus* spp. *Streptococcus* spp.	Bacterial
Adzitey et al.[36]	2011	Tamale (Northern Region)	Markets	Raw beef samples	*Streptococcus* spp. *Salmonella* spp. *Escherichia coli* *Staphylococcus* spp.	Bacterial
Adzitey et al.[37]	2014	Yendi (Northern Region)	Markets	Raw beef	*Staphylococcus* spp. *Streptococcus* spp. *Bacillus* spp. *Proteus* spp. *Escherichia coli* *Mucor* spp. *Pseudomonas* spp.	Bacterial `
Adzitey et al.[38]	2015	Bolgatanga (Upper East Region)	Markets	Fresh and smoked guinea fowl meat	*Staphylococcus* spp. *Streptococcus* spp. *Proteus* spp. *Salmonella* spp. *Bacillus* spp. *Escherichia coli* *Pseudomonas* spp.	Bacterial
Agbodaze et al.[39]	2005	Accra central (Greater Accra Region)	Street	Khebab	*Escherichia coli* *Staphylococcus* spp.	Bacterial

(Continued)

Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Akabanda et al.[40]	2010	Paga Navrongo Bolgatanga (Upper East Region)	Nunu production sites	Nunu	*Enterobacter* spp. *Klebsiella* spp. *Escherichia coli* *Proteus vulgaris* *Shigella spp.* *Lactobacillus* spp. *Leuconostoc* spp. *Lactococcus* spp. *Enterococcus* spp. *Streptococcus* spp. *Saccharomyces cerevisiae*, *Saccharomyces pastorianus* *Candida kefyr* *Yarrowia lipolytica*, *Candida stellata* *Kluyveromyces maxianus* *Zygosaccharomyces bisporus* *Zygosaccharomyces rouxii*	Bacterial Fungal
Amissah & Owusu[41]	2012	Koforidua (Eastern Region)	Street food vendors	Fufu Waakye Soup Sauce and goat meat	*Escherichia coli* *Staphylococcus aureus*	Bacterial
Amissah-Reynolds et al.[86]	2019	Accra (Greater Accra Region)	Street food vendors	Ready-to-eat vegetable salads	*Giardia lamblia* *Entamoeba histolytica* *Moniezia* spp. *Trichuris trichiura* *Entamoeba coli*	Parasitic
Amoah et al.[87]	2023	Kejetia, Ejura, Ejisu (Ashanti Region)	Markets	Vegetables Green pepper Cucumber Lettuce Carrot Green onions Tomatoes	*Entamoeba histolytica* *Ascaris lumbricoides* *Giardia lamblia* *Hookworm* *Enterobius vermicularis* *Trichuris trichiura* *Stronglyoides stercoralis* *Isospora belli* *Taenia* spp.	Parasitic
Ampaw[42]	2018	Accra (Greater Accra Region)	Street food vendors	Khebab (Raw and grilled)	*Listeria monocytogenes*	Bacterial
Amponsah et al.[43]	2018	Coastal areas	Fish markets	Smoked sardine	*Clostridium perfringens* *Enterococcus* spp.	Bacterial
Anachinaba et al.[44]	2015	Bolgatanga (Upper east Region)	Mobile clinic shops for beef	Fresh beef Smoked beef Fresh pork Smoked pork	*Staphylococcus* spp. *Streptococcus* spp. *Salmonella* spp. *Klebsiella* spp. *Escherichia coli*	Bacterial
Andoh et al.[45]	2014	Accra (Greater Accra Region)	Retail shops	Milk-based powdered beverages	*Aerobic mesophiles*	Bacterial
Ansah et al.[46]	2009	Tamale (Northern Region)	Open-air market	Raw eggs	*Escherichia coli* *Corynebacterium* spp. *Streptococcus* spp. *Mucor* spp. *Aspergillus* spp.	Bacterial Fungal

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Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Asuming-Bediako et al.[47]	2022	Accra (Greater Accra Region)	Wet markets and supermarkets	Raw chicken	*Campylobacter jejuni*	Bacterial
Ayamah et al.[48]	2021	Kumasi (Ashanti Region)	Street food vendors	Khebab (from beef, chevon and gizzard)	*Escherichia coli* *Staphylococcus aureus*	Bacterial
Ayeh-kumi et al.[49]	2014	Accra (Greater Accra Region)	Retail markets	Tiger nuts	*Klebsiella oxytoca* *Enterobacter cloacae* *Enterobacter* spp. *Proteus vulgaris* *Staphylococcus* spp. *Cryptosporidium parvum* *Ancylostoma duodenale* *Strongyloides stercoralis* *Cyclospora cayetanensis*	Bacterial Parasitic
Baah et al.[50]	2022	Accra (Greater Accra Region)	Meat vending shops	Beef Goat meat Chicken	*Escherichia coli* *Aeromonas hydrophila* *Vibrio cholerae* *Klebsiella pneumoniae* *Aeromonas veronii* *Serratia plymuthica* *Pantoea* spp. *Moellerella wisconsensis* *Acinetobacter baumannii* *Vibrio* spp. *Enterobacter cloacae* *Vibrio alginolyticus* *Pseudomonas luteola* *Proteus mirabilis* *Salmonella enteritidis* *Citrobacter koseri* *Yersinia enterocolitica* *Shigella flexneri* *Enterobacter aerogenes* *Citrobacter freundii* *Rahnella aqualitis* *Serratia odorifera* *Citrobacter youngae* *Klebsiella oxytoca* *Providencia rettgeri* *Acinetobacter iwoffi* *Serratia rubidaea* *Kluyvera* spp. *Pasteurella multocida* *Yersinia ruckeri* *Stenotrophomonas maltophilia* *Pasteurella pneumotropica*	Bacterial
Bakobie et al.[51]	2017	Tamale (Northern Region)	Retail markets	Spices	*Escherichia coli* *Salmonella* spp.	Bacterial
Bardoe et al.[52]	2023	Yeji (Bono East Region)	Fish processing sites	Smoked fish	*Escherichia coli* *Staphylococcus* spp.	Bacterial

(Continued)

Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Boampong et al.[53]	2023	Kumasi (Ashanti Region)	Bus terminals Local markets	Ready-to-eat cut fruits Pineapple Pawpaw Watermelon Sugarcane Tiger nut	*Enterococci* spp. *Escherichia coli* *Salmonella* spp. *Shigella* spp. *Ascaris* spp. *Hookworm* *Trichuris trichiura* *Strongyloides stercoralis* *Enterobius vermicularis* *Entamoeba coli* *Entamoeba histolytica* *Giardia lamblia* *Isospora belli* *Cryptosporidium parvum* *Cyclospora cayetanensis*	Bacterial Parasitic
Dankwa et al.[88]	2018	Cape Coast (Central Region)	Local markets	Tomato Cabbage Carrot Lettuce Spring onion Green pepper	*Stronglyoides* spp. *Hookworm* *Trichuris trichiura* *Ascaris lumbricoides* *Entamoeba coli*	Parasitic
Danso et al.[91]	2017	Ejura (Ashanti Region)	Maze farms	Maize	*Aflatoxin* *Fumonisin*	Mycotoxin
Darko et al.[84]	2017	Kumasi (Ashanti Region)	Hotel restaurant	Ready-to-eat foods Fufu Boiled plain rice Beef sauce Goat light soup Fresh pepper sauce Chicken and vegetable sauce	*Eurotium chevalien* *Cladosporium herbarum* *Eurotium amsteloclami* *Cladosporium herbarum* *Eurotium amsteloclami* *Fusarium oxysporum* *Eurotium chevalien* *Cladosporium herbarum* *Eurotium Amsteloclami*	Fungal
Dela et al.[54]	2023	Accra (Greater Accra Region)	Street food vendors	RTE foods such as; Ampesi Banku Beans Bofloat/koose/ Bread Fried egg Fried fish /meat Fried pepper (shitor) Fried rice Gari Grinded pepper “Hausa koko” (porridge) Indomie/spaghetti Jollof Kenkey Rice Salad Soup Stew Waakye	*Enterobacter* spp. *Citrobacter* spp. *Enterococcus faecalis* *Pseudomonas* spp. *Klebsiella pneumoniae* *Aeromonas* *Escherichia coli* *Klebsiella oxytoca* *Staphylococcus* spp. *Acinetobacter* spp. *Proteus mirabilis* *Escherichia* spp. *Serratia ficaria* *Vibrio* spp.	Bacterial
Donkor et al.[55]	2007	Accra (Greater Accra Region) Kumasi (Ashanti Region)	Market agents	Raw milk	*Yersinia* spp. *Klebsiella* spp. *Proteus* spp. *Enterobacter* spp. *Escherichia coli* *Staphylococcus* spp. *Bacillus* spp. *Mycobacterium* spp.	Bacterial

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Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Duedu et al.[89]	2014	Accra (Greater Accra Region)	Open air markets Supermarkets	Carrot Onion Tomato Green bell pepper Cabbage Lettuce	*Cryptosporidium parvum* *Entamoeba histolytica* *Giardia lamblia* *Cyclospora cayentenesis* *Isospora belli* *Entamoeba coli* *Strongyloides stercoralis* *Hookworm* *Trichuris trichiuria* *Enterobius vermicularis* *Faciolopsis buski*	Parasitic
Duwiejuah et al.[89]	2022	Tamale (Northern Region)	Retail markets	Smoked fish	*Shigella* spp. *Salmonella* spp. *Escherichia coli.*	Bacterial
Essiaw-Quayson[56]	2017	Kumasi (Ashanti Region)	Markets and bus terminals	Fresh cut fruits and vegetables Pineapple Pawpaw Watermelon Sugar cane Tiger nut	*Enterococci* spp. *Fungi* *Ascaris* spp. Hookworm *Trichuris trichiura* *Strongyloides stercoralis* *Enterobius vermicularis* *Entamoeba coli* *Entamoeba histolytica* *Giardia lamblia* *Isospora belli* *Cryptosporidium parvum oocysts* *Cyclospora cayetanensis*	Parasitic Bacterial
Fegloi & Sakyi[57]	2012	Kumasi (Ashanti Region)	Bus terminals	Ice kenkey Cocoa drink Fufu Ready-to-eat pepper Salad Macaroni	*Staphylococcus* spp. *Bacillus* spp. *Klebsiella* spp. *Aeromonas* spp. *Enterobacter* spp. *Citrobacter* spp. *Staphylococcus aureus* *Escherichia coli* *Pseudomonas aeruginosa*	Bacterial
Fung et al.[58]	2011	Kumasi (Ashanti Region)	Cafeterias Street vending sites	Salad	*Salmonella* spp.	Bacterial
Futagbi et al.[59]	2016	Accra (Greater Accra Region)	Retail markets	Mangoes	Total coliforms Faecal coliforms	Bacterial
Jimma et al.[60]	2022	Tamale (Northern Region)	Street vendors Supermarkets	Locally produced Fresh juice samples Industrially produced fresh juice samples	*Escherichia coli* *Salmonella* spp.	Bacterial
Kortei et al.[92]	2021	Various Regions in Ghana	Local markets	Maize	Aflatoxin Ochratoxin A	Mycotoxin
Kortei et al.[93]	2021	All regions in Ghana	Markets	Groundnut pastes and raw groundnut	Total aflatoxins AF B1 AFB2 AFG1 AFG2	Mycotoxin

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Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Kortei et al.[61]	2020	Accra (Greater Accra Region)	Restaurant	Mixed vegetable salad	*Escherichia coli* *Bacillus cereus* Enterobacteriaceae Yeasts and molds	Bacterial Fungal
Kortei et al.[85]	2021	Ho (Volta Region)	Retail market	Solom (millet beverage)	*Aspergillus* spp. *Rhizopus stolonifer* *Mucor racemosus* *Fusarium oxysporum* *Penicillium digitatum* *Cladosporium* spp. *Rhodotorula sp.*	Fungal
Kudah et al.[90]	2018	Koforidua (Eastern Region)	Vegetable Farms	Spring onion Lettuce Tomatoes Carrot	*Strongyloides stercoralis* *Balantidium coli* *Fasciola* spp. *Cryptosporidium* oocysts	Parasitic
Madilo et al.[62]	2023	Bolgatanga Navrongo Bongo Chiana (Upper East Region)	Street vendors	Groundnut	*Staphylococcus* spp. *Proteus* spp. *Escherichia coli* *E. coli* 0157:H7 *Bacillus* spp. *Micrococcus* spp. *Rhizopus* spp. *Saccharomyces cerevisiae* *Aspergillus* spp. *Fusarium* spp. *Mucor* spp. *Eurotium* spp.	Bacterial Fungal
Mahami et al.[63]	2023	Accra (Greater Accra Region)	Vegetable farms	Lettuce	*Acinetobacter baumannii* *Citrobacter freundii* *Enterobacter asburiae* *Klebsiella variicola*	Bacterial
Mensah et al.[64]	2022	Accra (Greater Accra Region)	Retail outlets	Raw chicken	*Escherichia coli*	Bacterial
Musah et al.[65]	2014	Accra (Greater Accra Region)	Bus stations	Hibiscus tea (Bissap/sobolo)	*Bacillus* spp. *Klebsiella* spp. *Pseudomonas* spp. *Streptococcus* spp. *Staphylococcus aureus* *Escherichia coli* *Aspergillus* spp.	Bacterial Fungal
Nkekesi et al.[66]	2023	Ho (Volta Region)	Street vendors	Grilled beef sausage	*Staphylococcus aureus* *Escherichia coli* *Bacillus cereus* *Salmonella* spp. *Aspergillus* spp. *Fusarium* spp. *Penicillium* spp. *Mucor* spp. *Rhodotorula* spp. *Rhizopus* spp.	Bacterial Fungal
Nyarko et al.[67]	2011	Cape Coast (Central Region)	Local Markets	Tiger nuts	*Bacillus* spp. *Escherichia coli* *Enterococcus* spp. *Pseudomonas aeruginosa* *Staphylococcus aureus* *Streptococcus* spp. *Enterobacter cloacae*	Bacterial

(Continued)

Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Obeng et al.[68]	2018	Accra (Greater Accra Region)	Markets	Tomato	*Bacillus* spp. *Citrobacter* spp. *Citrobacter koseri* *Enterobacter* spp. *Enterobacter cloacae* *Klebsiella* spp. *Klebsiella oxytoca* *Klebsiella pneumoniae* *Proteus mirabilis* *Pseudomonas aeruginosa* *Shigella* spp.	Bacterial
Obodai et al.[69]	2011	Tema (Greater Accra Region)	Smoking sites	Smoked sardine (sardinella aurita)	Coliforms *Escherichia coli* Yeasts and molds	Bacterial Fungal
Olu-taiwo et al.[70]	2021	Accra (Greater Accra Region)	Street vendors	Watermelon Sliced pawpaw	*Citrobacter koseri* *Citrobacter* spp. *Enterobacter* spp. *Klebsiella pneumoniae* *Klebsiella* spp. *Proteus vulgaris* *Pseudomonas* spp. *Staphylococcus aureus* *Staphylococcus epidermidis*	Bacterial
Olu-Taiwo et al.[71]	2021	Accra (Greater Accra Region)	Open markets	Raw beef	*Acinetobacter* spp. *Citrobacter* spp. *Citrobacter diversus* *Enterobacter* spp. *Klebsiella* spp. *Klebsiella oxytoca* *Proteus vulgaris* *Staphylococcus aureus* *Staphylococcus* spp.	Bacterial
Owusu-Kwarteng et al.[72]	2018	Tamale (Northern Region)	Open air markets	Raw cow milk Boiled milk Nunu	*Listeria monocytogenes*	Bacterial
Owusu-kwarteng et al.[73]	2017	Tamale (Northern Region)	Cattle farms	Raw milk Nunu Waagashie	*Bacillus cereus*	Bacterial
Parry-Hanson Kunadu et al.[74]	2018	Accra (Greater Accra Region)	Farms	Raw milk Yoghurt Ghee Boiled milk "Nunu" "Brukina" Raw "wagashi" Fried "wagashi"	*Salmonella enterica* *Staphylococcus aureus* *Escherichia coli* *E. coli* 0157:H7	Bacterial
Pesewu et al.[75]	2014	Accra (Greater Accra Region)	Street food vendors	Mixed Vegetable salads	*Escherichia coli* *Staphylococcus aureus* *Klebsiella* spp. *Bacillus* spp.	Bacterial
Quansah et al.[76]	2018	Accra (Greater Accra Region)	Vegetable farms	Lettuce Cabbage African spinach African eggplant leaves Roselle leaves Jute leaves	*Enterococcus* spp. *Salmonella* spp.	Bacterial

(Continued)

Table 2. (Continued)

REFERENCE	YEAR	STUDY SITES	SAMPLING POINT	SAMPLE TYPE	MICROBIOLOGICAL HAZARDS	HAZARD GROUP
Quarcoo et al.[77]	2022	Accra (Greater Accra Region)	Farm	Lettuce	*Escherichia coli*	Bacterial
Sackey[78]	2001	Accra (Greater Accra Region)	Poultry farms Super markets Open markets	Chicken carcasses	*Salmonella* spp. *Campylobacter* spp. *Escherichia coli* *Shigella* spp.	Bacterial
Samari et al.[94]	2022	Accra (Greater Accra Region)	Markets	Cloves Negro pepper Cumin Calabash nutmeg	*Aflatoxin*	Mycotoxins
Soriyi et al.[79]	2008	Accra (Greater Accra Region)	Market	Fresh beef	*Escherichia coli* *Staphylococcus aureus* *Bacillus cereus* *Clostridium perfringens*	Bacterial
Yafetto et al.[80]	2019	Cape Coast (Central Region)	Grocery shops	Cabbage Lettuce Scallions	*Enterobacter* spp. *Escherichia coli* *Klebsiella* spp. *Salmonella* spp. *Serratia marcescens* *Staphylococcus* spp. *Aspergillus* spp. *Candida* spp. *Fusarium* spp. *Penicillium* spp. *Rhodotorula* spp.	Bacterial Fungal
Yafetto et al.[81]	2019	Cape Coast (Central Region)	Meat retail shops	Beef Chevon	*Escherichia coli* *Klebsiella* spp. *Nocardia* spp. *Salmonella* spp. *Staphylococcus* spp. *Streptococcus* spp. *Aspergillus* spp. *Candida* spp. *Fusarium* spp. *Penicillium* spp. *Rhodotorula* spp.	Bacterial Fungal
Yar et al.[82]	2020	Kumasi (Ashanti Region)	Cold stores	Raw chicken	*Escherichia coli* *Salmonella* spp. *Klebsiella* spp. *Staphylococcus aureus* *Cladosporium* spp. *Aspergillus* spp. *Penicillin* spp. *Rhizopus* spp.	Bacterial Fungal

Local foods
*Ayoyo—leafy green vegetable (Jute mallow)
*Fufu—Pounded boiled cassava, yam and plantain
*Hausa koko—Millet pudding
*Waakye—Boiled rice and beans
*Tuo-zaafi—Stiff porridge made from maize or millet flour.
*Solom—Millet beverage
*Khebab—Skewered and grilled meat; typically made from lamb, beef or chicken.
*Nunu—Fermented yogurt-like beverage
*Brukina/Burchina—Local beverage made from ground millet and pasteurised milk.
*Wagashie/wagashi/Waagashie—Fermented Curd cheese.

Studies included in this review assessed microbiological hazards in different food samples (Table 2), including vegetable and fruit samples (carrot, onion, tomato, roselle leaves, jute leaves, African spinach, African eggplant, cabbage, cucumber, lettuce, green bell pepper, pawpaw, mango, sugarcane, pineapple, and watermelon), cereal and legumes and their products (maize, boiled rice, "solom"—a local millet beverage, tiger nuts, and groundnut paste), dairy products (raw milk, boiled milk, yogurt, "nunu"—a local milk drink, and "woagashie"—a local cheese made from cow's milk), meat

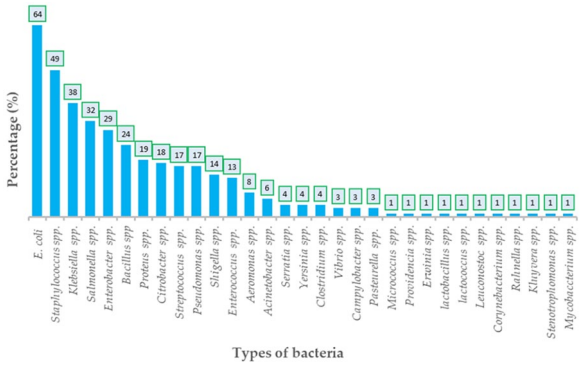

Figure 2. Percentage frequency of bacterial isolates found in all food samples in this review.

(beef, goat meat, and grilled beef sausage), chicken, raw and smoked fish (*Sardinella aurita*), spices (cloves, negro pepper, cumin, calabash nutmeg), "fufu"—a local delicacy prepared from boiled cassava, yam, and/or plantain, "tuo-zaafi"—a local staple prepared from maize or millet flour, and hibiscus tea ("bissap/sobolo").

Foodborne microbiological hazards

Bacteria: Of the studies reviewed, 85% (61/72) reported on bacterial hazards in various foods.[23-83] A total of 31 different genera of bacteria were isolated from both ready-to-eat (RTE) foods and raw foods, as shown in Figure 2. The most common bacterium reported was *Escherichia coli* (46/72, 64%). It was most detected in RTE vegetable salads, cabbage, lettuce, raw beef, raw chicken, raw goat meat, "Hausa koko", "khebab," as well as fresh and smoked fishes, with individual prevalence ranging from 2.1% to 100%.[23-41,44,46,48,50-55,57,60-62,64-67,69,74,75,77-83] The highest prevalence (100%) was recorded in lettuce and cabbage samples from a vegetable farm in Kumasi.[26] *Staphylococcus* spp. was the second most isolated bacterium, reported by 44% (32/72) of the studies[23,25,27-29,31,33,35-39,41,44,48,49,52,54,55,57,62,65-67,70,71,74,75,79-82]; 19 of these 32 studies specifically reported on *Staphylococcus aureus*, with individual prevalence ranging from 4% to 97%.[23,25,27-29,31,33,41,48,57,65-67,70,71,74,75,79,82] It was most detected in raw beef, chicken, and grilled beef sausage. The highest prevalence (97%) was recorded in "tuo-zaafi" sampled from Tamale.[25] *Salmonella* spp. was reported by 32% (23/72)[23-25,28,29,31,35,36,38,44,50,51,53,58,60,66,74,76,78,80-83] from foods such as raw beef, chicken, chevon, salad, mixed spices, and locally produced fruit juices. The prevalence of *Salmonella* spp. ranged from 1% to 73%. The highest prevalence was recorded in RTE vegetable salad. *Klebsiella* spp. was reported by 28% (20/72) of the studies included,[27,31,33,34,40,44,49,50,54,55,57,63,65,68,70,71,75,80-82] with prevalence ranging from 0.4%[50] to 63%.[34] Most commonly isolated species were *Klebsiella pneumoniae* and *Klebsiella oxytoca. Bacillus* spp. was reported by 24% (17/72) of the studies.[24,28,31,33,37,38,55,57,61,62,65-68,73,75,79] It was most common in vegetable salad and raw beef, with individual prevalence ranging from 10% to 93%. Also, *Enterobacter* spp. was reported by 22% (16/72) of the studies,[31,33,34,40,49,50,54,55,57,61,63,67,68,70,71,80] with prevalence ranging from 1% to 71%. *Proteus* spp. was also reported by 19% (14/72) of the studies, with prevalence ranging from 1% to 38%.[27,33,34,37,38,40,49,50,54,55,62,68,70,71] *Proteus mirabilis* and *Proteus vulgaris* were the most isolated *Proteus* species.

Other bacteria isolated were *Streptococcus* spp. (17%, 12/72), with prevalence between 3% and 11%,[28,33,35-38,40,44,46,65,67,81] *Pseudomonas* spp. (17%, 12/72), with prevalence between 1% and 14%,[27,31,33,37,38,50,54,57,65,67,68,70] *Shigella* spp. (14%, 10/72), with prevalence between 1% and 77%,[23-25,28,40,50,53,68,78,83] *Enterococcus* spp. (13%, 9/72), with prevalence between 6% and 16%,[33,35,40,43,53,54,56,67,76] *Citrobacter* spp. (11%, 8/72), with prevalence between 0% and 6%,[33,50,54,57,63,68,70,71] and *Aeromonas* spp. (7%, 5/72), with prevalence between 2% and 21%.[27,31,50,54,57]

Also recorded in this study were *Acinetobacter* spp. (6%, 4/72),[50,54,63,71] *Serratia* spp. (6%, 4/72),[34,50,54,80] *Clostridium* spp. (4%, 3/72), *Yersinia* spp. (4%, 3/72),[31,50,55] *Vibrio* spp. (3%, 2/72),[50,54] and *Campylobacter* spp. (3%, 2/72).[47,78] *Erwinia* spp.[34] *Micrococcus* spp.,[62] *Lactobacillus* spp., *Lactococcus* spp., *Leuconostoc* spp.,[40] *Corynebacterium*,[46] and *Mycobacterium* spp.[55] were reported by one study each. *Rahnella* spp., *Providencia* spp., *Kluyvera* spp., *Pasteurella* spp., and *Stenotrophomonas* spp. were all reported by Baah et al.[50]

Fungi: In all, 14/72 articles reported on various fungal species, as detailed in Figure 3. These fungi were mostly isolated from RTE vegetable salads, smoked fishes (tuna/mackerel) "solom," "fufu," hibiscus tea, "nunu," raw egg, beef, and chicken.[28,34,40,46,61,62,65,66,69,80-82,84,85] The most isolated fungal species was *Aspergillus* spp. (14%, 10/72),[28,34,46,62,65,66,80-82,85] followed by *Penicillium* spp. (10%, 7/22),[28,34,66,80-82,85] and *Fusarium* spp. (8%,6/72).[62,66,80,81,84,85] Other fungal species identified were *Rhizopus* spp. (7%, 5/72),[34,62,66,82,85] *Rhodotorula* spp. (7%, 5/72),[28,66,80,81,85] *Mucor* spp. (7%, 5/72),[37,46,62,66,85] *Candida* spp. (4%, 3/72),[40,80,81] *Cladosporium* spp. (4%, 3/72),[82,84,85] *Saccharomyces* spp. (3%, 2/72),[40,62] and *Eurotium* spp. (3%, 2/72).[62,84] *Carvulania* spp.[28] *Geotrichum* spp., *Paecilomyces* spp.,[34] *Zygosaccharomyces* spp., and *Yarrowia* spp.[40] were each reported by one study.

Fungal counts reported by Aboagye et al.[28] for "sobolo" and "asaanaa" ranged between 2.29–4.86 $\log_{10}$ CFU/ml and 2.098–4.23 $\log_{10}$ CFU/ml, respectively. Toxigenic fungal species, including those from the *Aspergillus*, *Fusarium*, and *Penicillium* genera, were isolated from these local drinks.[28] The study by Boampong et al.[53], recorded a high fungal count of 3.73 log CFU/g in watermelon. The count of fungal colonies obtained from vegetable sauce, fried chicken, mixed salad, fried rice, and goat light soup, investigated by Darko et al.[84] exceeded the acceptable levels set by the WHO. These food samples

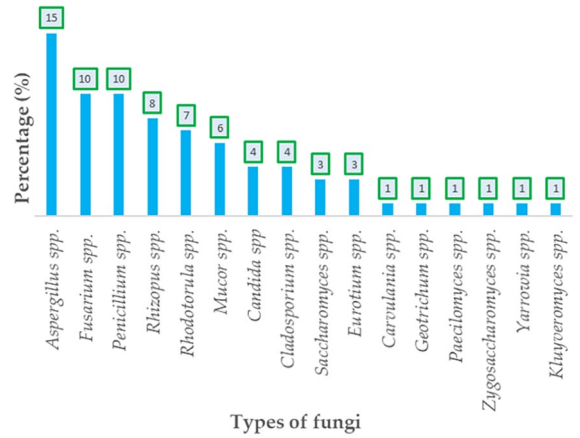

Figure 3. Percentage frequency of fungal isolates found in all food samples in this review.

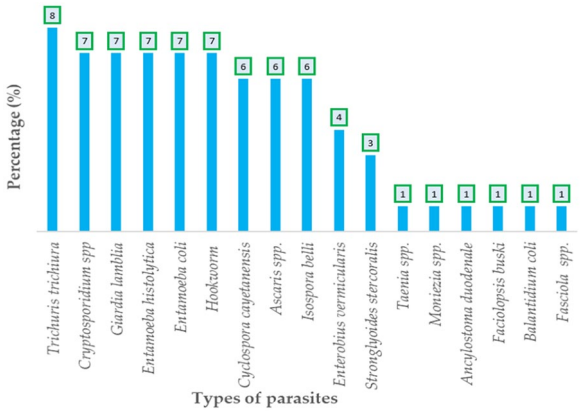

Figure 4. Percentage frequency of parasitic organisms found in all food samples in this review.

reported fungal loads between 2.2 log CFU/g and 4.0 log CFU/g, indicating that these foods could potentially transmit these fungi to unsuspecting consumers.[84] Also, Kortei et al.[85] reported the fungal counts in "solom" (a millet beverage). The counts observed ranged from 1.68 ± 0.8 to 4.11 ± 0.9 $\log_{10}$ CFU/ml. The study by Nkekesi et al.[66] reported fungal contamination in street-vended grilled beef sausage in Ho. The total fungal counts varied from 0.0 to 9.83×10^3 CFU/g. The species identified in the samples included *Aspergillus* spp. and *Rhizopus* spp.

Parasites: Of the studies included in this review, 11% (8/72) reported on the identification of various parasites as contaminants in various food samples, as illustrated in Figure 4.[49,53,56,86,87,88,89,90] These parasites were isolated from vegetable salads, tiger nuts, fresh vegetables such as cabbage, lettuce, carrot, tomato, cucumber, green pepper, green onions, and fresh cut fruits such as pawpaw and pineapple. The most isolated parasite was *Trichuris trichiura* (8%, 6/72)[53,56,86,87,88,89]; detected mostly in lettuce, cabbage, and green onions.[87,88,89]

Other parasites isolated include *Cryptosporidium* spp. (7%, 5/72),[49,53,56,89,90] *Giardia lamblia* (7%, 5/72),[53,56,86,87,89] *Entamoeba histolytica* (7%, 5/72),[53,56,86,87,89] *Entamoeba coli* (7%, 5/72),[53,56,86,88,89] hookworm (7%, 5/72),[53,56,87-89] *Cyclospora cayetanensis* (6%, 4/72),[49,53,56,89] *Ascaris* spp. (6%, 4/72),[53,56,87,88] *Isospora belli* (6%, 4/72),[53,56,87,89] *Enterobius vermicularis* (4%, 3/72),[53,56,87,89] *Strongyloides stercoralis* (3%, 2/72),[87,88] *Taenia* spp. (1%, 1/72),[87] *Moniezia* spp. (1%, 1/72),[86] *Ancylostoma duodenale*,[49] *Faciolopsis buski*,[89] *Balantidium coli*, and *Fasciola* spp.[90] The highest contamination rates were detected on vegetables such as spring onion (97%),[90] lettuce (76.2%)[88], and cabbage (66.7%).[88]

Mycotoxins: Among the 72 studies analysed, four (6%, 4/72) investigated the presence of mycotoxins in various food samples.[91-94] These mycotoxins were detected in maize, groundnut paste, and spices. Aflatoxins and fumonisin were both detected in maize samples investigated by Danso et al.[91] from the Ashanti Region. The mean levels of aflatoxin detected on-field in the study (7.2–14.2 ppb) were all below the limit of 15 ppb set by the Ghana Standards Authority (GSA).[91] However, the levels detected in heaping and post-drying stages (16.6–24.9 ppb) were above the threshold. Out of 153 individual samples tested for aflatoxin, 29 samples were above the threshold.[91] Fumonisin levels detected ranged between 0.7 and 1.9 ppm, well below the threshold.[91]

Out of a total of 180 maize samples tested by Kortei et al.[92], 131 tested positive for aflatoxin and 103 tested positive for ochratoxins. Out of the 180 samples analysed for total aflatoxins, 127 (70.50%) exceeded the limit set by the European Food Safety Authority (EFSA). The levels of aflatoxin in these samples ranged from 4.27 to 441.02 µg/kg. Similarly, 116 samples (64.44%) surpassed the limit set by the GSA, with concentrations ranging from 10.18 to 441.02 µg/kg.[92] Regarding ochratoxin A (OTA), 94 samples (52.22%) exceeded the tolerable limit established by the EFSA. The OTA concentrations in these samples ranged from 4.00 to 97.51 µg/kg. Additionally, 89 samples (49.44%) surpassed the limit set by the GSA, with OTA levels ranging from 3.30 to 97.51 µg/kg.[92]

Kortei et al.[93] investigated the presence of aflatoxins in groundnut and groundnut paste. The study revealed that out of the 80 samples examined, 49 (61.25%) tested positive for Aflatoxin B1, with concentrations ranging from 0.38 ± 0.04 µg/kg to 230.21 ± 22.14 µg/kg. The same proportion of samples tested positive for total aflatoxins, with levels ranging from 0.38 ± 0.02 µg/kg to 270.51 ± 23.14 µg/kg. The limits set by the GSA and the EFSA were used as benchmarks for AFB1 and total aflatoxins (AF total) (5 and 10 µg/kg for GSA, and 2 and 4 µg/kg for EFSA). A total of 33 samples (41.25%) exceeded the limits for both AFB1 and total aflatoxins.[93]

Discussion

The findings of this review present an encouraging trend of research activities related to microbial food safety in Ghana. The majority of the studies (82%, 59 out of 72) were conducted between 2012 and 2023, while 18% (13 out of 72) were carried

out between 2001 and 2011. This indicates an upward trajectory in microbial food safety research in Ghana. This contradicts earlier reports by Saba & Gonzalez-Zorn,[17] which had characterised microbial food safety research in Ghana as "abysmal." Several of these studies were carried out in the Greater Accra, Ashanti, and Northern Regions, suggesting a limited geographical scope. Approximately, 78% of the total studies were conducted in these regions, with a particular emphasis on their capital cities (Accra, Kumasi, and Tamale). This finding aligns with reports by Botha et al.[95] and Saba & Gonzalez-Zorn[17], which identified these regions as having a high number of food safety research activities in Ghana compared to the other regions in the country. This could be attributed to a higher occurrence of food contamination in these regions.[95] Paudyal et al.[16] highlighted that food safety studies in Africa often exhibit a limited capacity, focusing on specific geographic areas within the countries under investigation, similar to the observation in this study.

The review reported various microbiological hazards, with the majority (85%) of the included studies reporting on bacterial hazards. Among these hazards, the most frequently isolated bacterial pathogens were *Escherichia coli*, *Staphylococcus* spp., *Salmonella* spp., and *Klebsiella* spp. These findings align with those of a similar review conducted by Makinde et al.[96] in 2020, which investigated the microbiological safety of RTE foods in low and middle-income countries. Specifically, *E. coli*, *Klebsiella* spp., and *Salmonella* spp. were the most commonly reported bacterial pathogens in that study. Additionally, findings from the meta-analysis of Paudyal et al.[16] that focused on selected African countries also identified *Escherichia coli*, *Staphylococcus* spp., and *Salmonella* spp. as the most studied pathogens in food. The presence of these pathogens in food poses a potential risk, rendering it unsafe for human consumption and posing a clear threat to consumer health.[16,96] These pathogens are responsible for diarrhoea, particularly among children under five years of age.[4] A report by Osei-Tutu & Anto[97] identified cholera, typhoid fever, shigellosis, and viral hepatitis as the four most clinically diagnosed foodborne diseases reported at a hospital in Accra, Ghana. All the pathogens responsible for these diseases were identified in foods in this study, except viral hepatitis.

In this review, *Escherichia coli* was found to be the most identified bacterial pathogen from both RTE and raw foods in Ghana. Notably, Shiga toxin-producing strains of *Escherichia coli* (*E. coli* 0157:H7) were identified in vegetable salads,[31] groundnut,[62] raw milk, boiled milk, "brukina," "nunu," and raw "wagashie" samples,[74] with overall prevalence ranging from 1.1% to 21%. In line with this finding, studies from other countries[98-101] have reported the presence of *E. coli* 0157:H7 in RTE food samples despite zero-tolerance policy against it (Todd, 2004). Wang et al.[102] reported a study which investigated an outbreak of *E. coli* 0157:H7 linked to spinach consumption in 26 states in the USA and Canada. Among 199 cases reported, three deaths occurred, while 16% developed acute renal failure and 51% required hospitalisation. The presence of this pathogen in RTE food poses a significant public health risk due to the severe illnesses it can cause, such as haemorrhagic or non-haemorrhagic diarrhoea, haemorrhagic colitis, haemolytic uremic syndrome, and thrombotic thrombocytopenic purpura.[103,104]

Other bacteria reported from RTE foods in this study included *Klebsiella* spp., *Shigella* spp., *Salmonella* spp., *Pseudomonas* spp., *Bacillus* spp., *Streptococcus* spp., *and Staphylococcus* spp.[23-25,28,30,39,41,49,53,54,57,60,62,65-67,70,74]. In this review, it was found that locally prepared drinks such as "asaanaa" and "sobolo" contained these harmful microorganisms, with many exceeding the acceptable limits set for RTE foods.[28,65] Jimma et al.[60] reported the presence of *E. coli* and *Salmonella* spp. in locally processed fruit juices, with microbial loads above the acceptable limits and found no traces of these organisms in industrially processed fruit juices. This finding is consistent with that of a study by Sultana et al.[105] from Bangladesh which found bacterial contamination in locally processed juices to be above tolerable limits, while industrially processed fruit juices had negligible counts. This finding suggests that locally prepared drinks are more susceptible to microbial contamination than industrially processed drinks, which could be attributed to good sanitation practices, addition of preservatives, and the use of automated and aseptic juice processers in the industries.[60,105]

Fruits and vegetables were identified in this review as common reservoirs of several microbial pathogens, predominantly, *E. coli*, *Salmonella* spp., *Shigella* spp., *Enterococci* spp., *Citrobacter* spp., *Staphylococcus* spp., and *Klebsiella* spp. in Ghana.[53,56,59,70] The review revealed that fresh-cut RTE fruits and vegetables are prone to contamination by various microorganisms, both pathogenic and non-pathogenic, due to the processes involved in their preparation and handling before and during sale.[53,70] Contrary to this finding, 10,070 samples of fresh-cut fruits and vegetables analysed for bacterial pathogens in Canada reported zero incidence of *Escherichia coli*, *Salmonella* spp., *Shigella* spp., and *Campylobacter* spp.[106] Proper handling and storage throughout the entire process of harvesting, processing, preparation, storage, and retail display are crucial to ensuring the safety of RTE fresh-cut fruits and vegetables for consumers.[107]

Also in this review, several bacteria were identified in raw beef and raw chicken samples.[29,31,33,36,37,44,47,50,64,71,78,79,81,82] The most commonly isolated bacteria from raw beef and chicken samples were *E. coli*, *S. aureus*, *Klebsiella* spp., *Salmonella* spp., *Klebsiella* spp., and *Bacillus* spp. This finding agrees with those of studies conducted by Mpundu et al.[108] and Madoroba et al.[109] in which *E. coli*, *Staphylococcus aureus*, *Salmonella* spp., and *Bacillus* spp. emerged as major contaminants in raw chicken and meat samples from Zambia and South Africa. The occurrence of these bacteria may be attributed to unhygienic practices both at slaughterhouses and retail shops as well as the water used in washing the meat before retail.[109] Also, these bacterial contaminations may be from the soil as most post-slaughter processes in abattoirs are done on the floor. According to Bhandare et al.[110]

it has been emphasised that a large number of abattoir and retail beef workers in developing countries lack proper training on, and awareness about, hygienic practices that could help reduce bacterial contamination in beef products.[111] Retailers must prioritise strict adherence to hygiene conditions, proper handling practices, and appropriate storage methods for meat products.[111] Moreover, it is essential to implement continuous monitoring of bacteriological profiles and loads at abattoirs and sales points to ensure the safety of these products.

The parasitic organisms reported in this review, *Trichuris trichiura*, *Cryptosporidium* spp. *Giardia lamblia*, *Entamoeba histolytica*, *Entamoeba coli*, *Hookworm*, *Cyclospora cayetanensis*, *Ascaris* spp., *Isospora belli*, *Enterobius vermicularis. Stronglyoides stercoralis*, *Taenia* spp., *Moniezia* spp., *Ancyclostoma duodenale*, *Faciolopsis buski*, *Balantidium coli*, and *Fasciola* spp., have been documented in various regions worldwide, as evidenced by studies conducted by Mohamed et al.,[112] Eraky et al.,[113] Said et al.,[114] and Chau et al.[115] In this review, these parasites were isolated from RTE salads, fruits, and vegetables.[49,53,56,86-90] Among the identified parasites, *Trichuris trichiura* was the most prevalent. This parasite is the known cause of trichuriasis—a condition characterised by inflammation of the colon, diarrhoea, bloody stools, weight loss, anaemia particularly in children.[116,117] A review conducted by Karshima 2018, reported these parasites (*Taenia* spp., *Ancylostoma duodenale*, *Ascaris lumbricoides*, *Enterobius vermicularis*, *Balantidium coli*, *Entamoeba coli*, *Strongyloides stercoralis*, and *Trichuris trichiura*) as major parasitic contaminants in fruits and vegetables in Nigeria as reported in this study. This finding emphasises the public health concern associated with the potential acquisition of parasitic infections through the consumption of contaminated fruits and vegetables. These contaminations may be due to water used for irrigation and washing of fruits and vegetables and also poor hygienic practices by food handlers.[87,88,118]

Various fungal species were reported in a number of studies in this review, predominantly in RTE foods such as boiled rice, vegetable salad, "fufu," "solom," "sobolo," grilled beef sausage, "nunu," groundnut, smoked fish (Mackerel, Tuna, and Sardine), cabbage, lettuce, and scallions. The analysis revealed that salads and vegetable dishes were the most heavily contaminated food items with fungi. The most reported fungal species in these foods were *Aspergillus* spp., *Fusarium* spp., and *Penicillium* spp. This finding agrees with that of a study by Izah et al.[119] which reported *Aspergillus* spp., *Fusarium* spp., *Mucor* spp., and *Penicillium* spp. in RTE foods in Nigeria. According to Hashem,[120] these fungi are known to produce mycotoxins such as aflatoxins and ochratoxins (produced by *Aspergillus* spp.), moniliformin and fumonisins (produced by *Fusarium* spp.), and citrinin and cyclopiazonic acid (produced by *Penicillium* spp.).[119-122] These mycotoxins could cause liver diseases, among other health complications.[120]

Some studies in this review identified the presence of some mycotoxins, specifically aflatoxins, fumonisin, and ochratoxin in maize, groundnuts, groundnut paste, and spices sold in local markets throughout Ghana. The findings revealed that a significant proportion of maize, groundnut, and spice samples, had aflatoxin levels that exceeded the established thresholds set by the GSA and the EFSA for total aflatoxins.[91-94] Aflatoxins could have adverse effects on human health, including teratogenic, carcinogenic, hepatotoxic, and mutagenic outcomes, even when consumed in small quantities.[123,124] In Ghana, maize and groundnut blend is a very popular complementary food for children.[125] A report by Ismail et al.[126] indicated that aflatoxin exposure during pregnancy and infancy, whether *in utero* or via breast milk, infant formula milk, and infant foods, has been associated with various health concerns, such as hindered growth and development, weakened immune system, and impaired liver function, particularly in African and Asian nations due to high exposure rates. This is major public health concern in Ghana due to a high rate of consumption of maize and maize products. Aflatoxin contamination in food also has economic implications. According Kortei et al.[92] elevated levels of aflatoxins in food samples could potentially lead to rejection during export, as they do not meet the required safety standards. It is important that good agricultural practices and good hygiene practices are implemented to prevent the formation of aflatoxins in food during storage.[92] The various hazards identified in this review have been reported to cause severe health complications, particularly in vulnerable populations, such as immunocompromised individuals, children, the elderly, and pregnant women.[127]

Conclusion

This review has provided an overview of the spectrum of several microbiological hazards in foods in Ghana that are of importance to public health. It has revealed that several foods, such as vegetable salads, fruits and vegetables, "khebab", meat (beef, goat chicken) and milk, commonly have high levels of microbial contaminations. The widespread contamination of food with such hazards (e.g., *Escherichia coli*, 0157:H7, *Staphylococcus* spp., *Klebsiella* spp., *Salmonella* spp., *Shigella* spp., *Aspergillus* spp., *Fusarium* spp., *Penicillium* spp., coupled with their toxins, and other parasitic contaminants), as documented in this review, could pose significant public health concerns, particularly for vulnerable populations. Consuming such foods could lead to illnesses, and in severe cases, death. It is essential that regulatory authorities rigorously enforce existing food safety laws and take proactive measures to ensure compliance particularly in the informal food sector. It is also important that food vendors and handlers adhere to safety standards, maintain proper personal hygiene, and adequately prepare food to protect the safety of consumers. Moreover, food safety research in Ghana must extend beyond the capital cities of Greater Accra, Ashanti, and Northern Regions to encompass a wider range of geographical areas. This is crucial for a comprehensive understanding of the unique food safety challenges that exist in other areas throughout the country. Although no articles in the review

investigated foodborne viruses, viral hepatitis was reported as a common foodborne illness in a Ghanaian hospital.[97] It is important that research is conducted in this area to better understand the impact of foodborne viruses on foodborne disease.

Limitation

This scoping review is subject to some limitations due to the heterogeneity of included studies. Despite using a standardised data extraction template, the studies included varied in design, methodology, food types, microbial hazards, and data reporting, making direct comparisons and analysis challenging. Additionally, the review primarily focused on published articles indexed in PubMed, Web of Science, Scopus, and Google Scholar, potentially excluding relevant grey literature and articles available in hard copy.

Author contribution

Conceptualisation, ESD; methodology, WKA, FCNK, and ESD; validation, FCNK, PBT-Q, and ESD; formal analysis, WKA, FCNK, PBT-Q, and ESD; resources, ESD; data curation, WKA, FCNK, PBT-Q, and ESD; writing—original draft preparation, WKA, FCNK, and ESD; writing—review and editing, WKA, FCNK, PBT-Q, and ESD; visualisation, WKA, FCNK, PBT-Q, and ESD; supervision, PBT-Q and ESD; funding acquisition, ESD.

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