Emerging Problems in Infectious Diseases

Microbial food safety in Ghana: a meta-analysis

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Abstract

Introduction: Food safety is a crucial factor in the growth of developing countries worldwide. In this study, we present a meta-analysis of microbiological food safety publications from Ghana.

Methodology: The search words "Ghana food safety", "Ghana food research", and "Ghana food bacteria" were used to search for microbiological food safety publications with related abstracts or titles in PubMed, published between 1997 and 2009. We obtained 183 research articles, from which we excluded articles concerning ready-to-eat microbial fermented foods and waterborne microorganisms as well as articles without abstracts. The criteria used for analysis of these publications were based on an assessment of methodological soundness previously developed for use in the medical field, with some modifications incorporated.

Results: The most predominant bacteria in Ghanain foods are *Enterobacter spp.*, *Citrobacter spp., Klebsiella spp.* and *Escherichia spp.,* which were found to be present in 65%, 50%, 46% and 38% respectively, of the food samples considered in the studies analysed. The most contaminated food samples were macaroni, salad, and milk. Although the methodological quality of the articles was generally sound, most of them did not give directions for future research. Several did not state possible reasons for differences between studies.

Conclusion: The microbiological food contamination in Ghana is alarming. However, we found that the downward trend in publications of microbial food safety articles is appalling. Hence a concerted effort in research on food safety is needed in Ghana to help curb the incidence of preventable food-borne disease.

Key words: meta-analysis; microbial food safety; public health; Ghana

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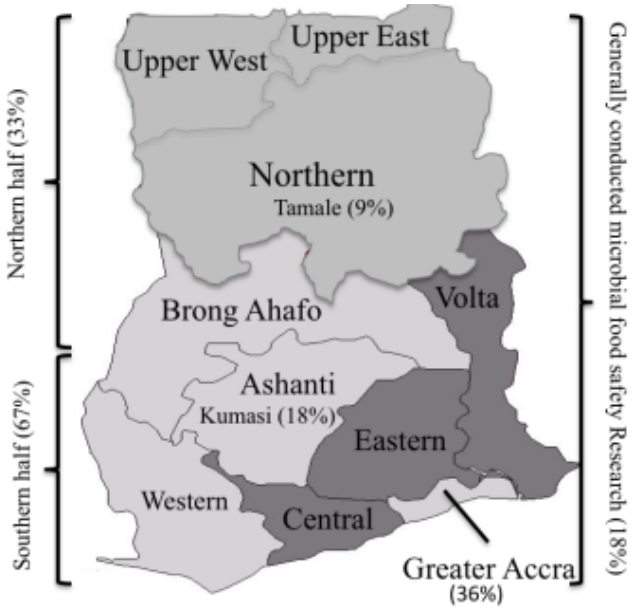
Introduction

Approximately 2.2 million deaths caused by diarrhoeal disease are recorded annually worldwide and most of these cases are attributed to contaminated food and water [1]. Although the vast majority of cases are mild, a significant number of cases are fatal and a high incidence of acute infections and chronic sequelae can lead to billions of dollars in medical costs, loss of productivity [2], and frequent recalls [3]. The problem of food safety is not only a problem in developing countries but also in developed countries, which have advanced food chain monitoring systems [4]. Food-borne diseases continue to be a matter of major concern worldwide despite important developments in reducing the incidence of certain pathogens in foods through better farm practices and food regulations [5]. In the United States food-borne diseases have been estimated to cause 76 million illnesses, 323,000 hospitalizations, and over 5,000 deaths annually [6]. The food production can be very complex with various stages which may allow routes of exposure, meaning that pathogen control is critical in the "farm to fork" food production continuum [7]. In developing countries, where a significant proportion of the annual budget of both governments and development partners is spent confronting food-borne diseases, food safety must be recognized and addressed. Minimizing the consumption of unsafe food, therefore, may help to ensure the good health of the population and may play a vital role in the economic progress of developing countries. Diarrhoea is the most common illness experienced by international travellers in developing tropical and semitropical regions [8]. The outbreak of the lethal strain of *Escherichia coli* in Europe in 2011 highlighted the limits of our present understanding of the evolutionary trends of new pathogens [9].

Meta-analysis combines and critically analyses the results of different scientific studies that address a set of related research hypotheses and can serve as a

Figure 1. Map of Ghana showing the current official regions and the distribution of microbial food safety of published articles involved in the meta-analysis



One article (9%) sought to investigate problems in Accra and Kumasi. One article (9%) investigated a problem in Accra, Kumasi and Tamale. The percentages presented on the left show the percentages of the microbial food safety articles involved in the meta-analysis taking into consideration the southern and northern halves of the country while that at the right shows research generally conducted.

reference point for finding important information. In this study we used meta-analysis to probe the microbial food safety articles on PubMed that concern Ghana. Our aim was to give a general view of microbial food safety research in Ghana, to guide future research, and to provide an information base for policy makers in formulating food safety policies.

Methodology

Criteria for selection of food safety articles

In this analysis, articles related to microbial food safety in Ghana from both local and international journals were searched in PubMed and meta-analysed to assess the state of microbial food safety in Ghana. The search was performed in August 2009 and covered papers from 1997-2009. Three search terms were used: "Ghana Food Safety", "Ghana Food Research" and "Ghana Food Bacteria", recovering 20, 183 and 83 publications respectively Articles relating to microbial food safety were first selected based on their titles and were further by their abstracts. Articles without abstracts (2) were excluded from this work as well as articles concerned with ready-to-eat microbial fermented foods and waterborne diseases. In total, 11 remaining articles were examined based on a quality assessment checklist that was originally created for the assessment and validation of methodological soundness [10], modified for increased applicability to food safety research [7]. Selected articles were grouped into three categories based on whether they addressed a specific intervention, addressed multiple interventions, or were general with specific interventions on food safety. As shown in Table 1, further sub-classifications were performed [7]. Under the food production sector in Table 1, publications can belong to more than one category. The food items investigated in the 11 articles were identified and analysed in conjunction with their respective isolated microbes, which were classified according to their frequency of occurrence in the food items. The same genera or species of microorganisms isolated from a food item in the same article were defined in this study as a single isolate. For instance, twenty isolates of *E. coli* found in the same food by name within the same article were considered as one *E. coli* isolate.

Results

Source and geographical distribution of articles

Eleven articles were chosen for this work based on the selection criteria described. The selected articles came from the following journals: three from *Acta Tropica* [11-13], two from the *Ghana Medical Journal* [14,15], two from the *International Journal of Microbiology* [16,17], and one each from the *East African Medical Journal* [18], the *Journal of Urban Health* [19], *Archives of Environmental Contamination and Toxicology* [20], and the *Bulletin of the World Health Organization* [21]. Published studies on food safety were observed to have mainly been based on research performed in the southern half of the country, with the majority of publications coming from the capital Accra and its environs (Figure 1). Information regarding the year of distribution of articles, food source studied, and bacterial species involved are shown in Table 1, although three of the articles did not isolate a pathogen [13,17,19].

Types of bacterial isolates and frequency in food

A total of 105 isolates were obtained from 26 food samples involved in the articles meta-analysed (Table 2). Of these 105 isolates, 5 (5%) were Gram-positive bacteria (*Bacillus spp*., *Campylobacter jejuni*, *Staphylococcus* spp., and *Mycobacterium* spp.), that were derived from four different food samples [11,14,15,16]. The vast majority of the bacterial strains isolated (95%) belong to the family

Table 1. Descriptive statistics of the 11 articles addressing microbial food safety interventions in Ghana published between 1997-2009

	Articles specific to one intervention (n = 7)	Articles specific to multiple interventions (n = 2)	General articles with a section on interventions (n=2)
Year of publication			
1997	0	0	1
2000	2	0	0
2001	0	1	0
2002	0	1	0
2003	1	0	0
2004	1	0	0
2005	1	0	0
2006	0	0	1
2007	1	0	0
2008	1	0	0
2009	0	0	0
Pathogen type			
Single bacterial species	3	0	0
Multiple bacterial species	2	2	1
Pathogen type not described	2	0	1
Food production sector			
Farm	2	1	1
Processing	1	0	0
Street food	4	1	1
Storage (cold store)	0	1	1
Post-processing	5	2	0
Vendors	3	1	0
Consumers	2	0	0
Commodity group			
Vegetables or crops	0	1	1
Poultry	1	0	1
Swine	1	0	0
Ruminants (beef, mutton, chevon)	3	0	0
Aquaculture, seafood, shellfish	0	0	0
Milk products	1	0	0
Mixed products	1	1	0

Enterobacteriaceae (Table 2). A single major study conducted in Accra was responsible for data on most of the isolates (83%) [21], of which 91% were identified to the species level. Of the other 10 publications, which isolated the remaining 17% of strains, only 23% of the isolates were identified to the species level, of which *E. coli* was the most identified species. The methodological qualities of the articles were critically appraised (Table 3).

Combining all the data, *Enterobacter* spp. were found in seventeen (65%) of the 26 food samples, while thirteen (50%) food samples contained *Citrobacter* spp. The abundances of other bacterial species are given in Table 2 and Figure 2. It is very surprising that only one of the articles in this work performed susceptibility tests on the isolated microorganisms against commonly used antibiotics [16].

Food types and associated bacterial species

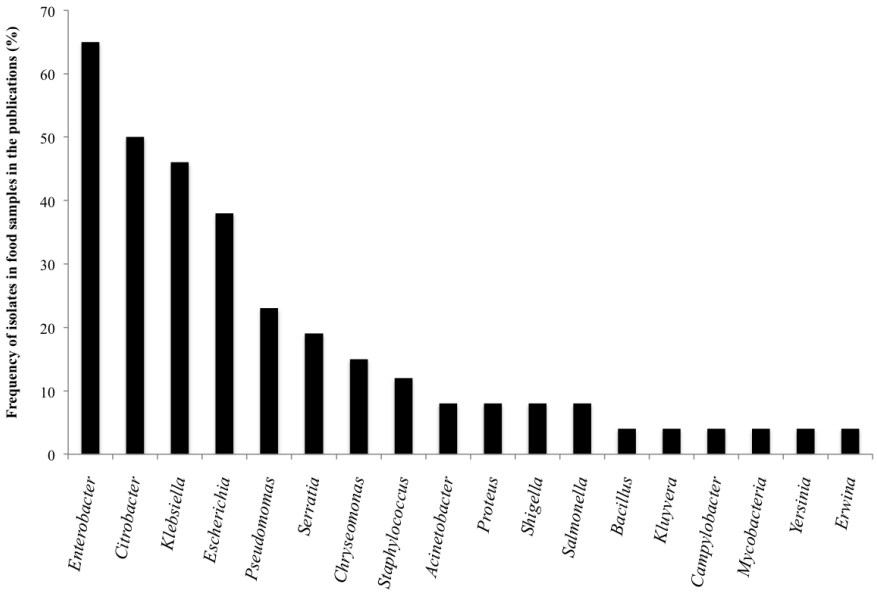
Of the twenty-six food samples, six (groundnut soup, light soup, okro soup, nkontomre stew and white oil) had only one bacterial species isolated. Two samples (salad and milk) had eight bacterial species isolates while four samples (fufu, beans, kenkey and tomato stew) each had three species isolated. Three samples (red pepper, gari and plantain) each had six bacterial species isolates. Four samples (chicken, shito, rice and yam) contained four bacterial species

Table 2. Different foods and the bacteria isolated from them in the 11 analyzed articles

Food	Bacterial Isolates
Chicken	*Shigella* spp. *(imported chicken)*[16], *Salmonella* spp.[16], *Cambylobacter jejuni*[16], *and E. coli*[16]
Kebab (beef and pork)	*Escherichia* coli[14], *and Staphylococcus* spp.[14]
Milk	*E. coli*[15], *Yersinia* spp.[15], *Klebsiella* spp.[15], *Proteus* spp.[15], *Enterobacter* spp.[15], *Staphylococcus* spp.[15], *Bacillus* spp.[15], *and Mycobacterium* spp.[15]
Koko	[21]*Chryseomonas luteola,* [17]*Shigella spp.*
Macaroni	*Shigella sonnei*[21], *Pseudomonas fluorescente/putida*[21], *K. pneumoniae*[21], *Enterobacter sakazakii*[21], *E. coli (enteroaggregative diffuse*[21]*), Citrobacter freundii*[21], *Serratia liquefaciens*[21], *Enterobacter cloacae*[21], *Enterobacter agglomerans*[21], *E. coli*[21], *Citrobacter diversus/amalonotica*[21], *Citrobacter spp.*[21], *Proteus mirabilis*[21], *Proteus* spp.[21], *Enterobacter amnigenus*[21] *and Pseudomonas cepacia*[21]
Salad	*Pseudomonas aeruginosa*[21], *S. liquefaciens*[21], *E. sakazakii*[21], *E.cloacae*[21], *P. fluorescens/putida*[21], *C. freundii*[21], *E. coli*[21], *and C. diversus/amanalotica*[21]
Shito (over cooked stew)	*Klebsiella cloacae*[21], *K. pneumoniae*[21], *E. cloacae*[21], *and E. coli*[21]
Tomato stew	*C. freundii*[21], *E. sakazakii*[21], *E. coli (enteroaggregative localized)* [21]
Nkontomre stew	*E. cloacae*[21]
Fish	*C. diversus*[21], *E. coli*[21], *C. luteola*[21], *P. fluorescens/putida*[21], *E. sakazakii*[21], *C. diversus/amalonatica*[21], *K. pneumoniae*[21]
Palm nut soup	*C. freundii*[21], *E. cloacae*[21]
Groundnut soup	*C. fruendii*[21]
Light soup (meat)	*Salmonella arizonae*[21]
Okro soup	*E. cloacae*[21]
White oil	*Pseudomonas* spp [21]
Red oil	*Escherichia hermanii*[21], *C. freundii*[21]
Red pepper	*K. pneumoniae*[21], *S. liquefaciens*[21], *Kluyvera* spp.[21], *E. cloacae*[21], *E. amnigenus*[21], *Citrobacter* spp. [21]
Beans	*C. freundii*[21], *K. pneumoniae*[21], [21]*E. cloacae*[21]
Kenkey	*Pseudomonas* spp. [21], *Klebsiella* spp.[11], *Staphylococcus* spp.[11]
Gari	*C. freundii*[21], *E. cloacae*[21], *C. luteola*[21], *Serratia funtida*[21], *E. aerogenes*[21], *E. agglomerans*[21]
Rice	*E. coli (enteroaggregative diffuse)*[21], *Serratia marcescens*[21], *K. pneumoniae*[21], *P. fluorescens/putida*[21]
Yam	*C. freundii*[21], *K. pneumoniae*[21], *Citrobacter* spp.[21], *C. luteola*[21]
Plantain	*Citrobacter* spp[21]., *K. pneumoniae*[21], *Acinetobacter* spp.[21], *Klebsiella* spp.[21], *Enterobacter* spp.[21], *C. freundii*[21]
Fufu	*C. diversus*[21], *E. cloacae*[21], *E. sakazakii*[21]
Waakye (rice and beans)	*Enterobacter* spp.[21], *Acinetobacter* spp.[21], *Erwina* spp.[21], *E. cloacae*[21], *K. pneumoniae*[21]
Akple/Banku	[1]*E. cloacae*[21], *K. pneumoniae*[21]

Koko = porridge made of fermented/dried corn
Nkontomre = leafy vegetable
Gari = dried-grated cassava
fufu = boiled cassava/plantain/yam pounded individually or mixed
Kenkey = made of boiled fermented corn dough
Banku = mixture of corn and cassava dough
Akple = solidified porridge made of only corn
The superscript numbers represent the reference numbers of the publications.

Figure 2. The frequency of the bacterial isolates found in all the food samples involved in the meta-analysis



A total of 26 food samples with 105 bacterial isolates were obtained in the 11 articles. Sixty-five percent of the total bacterial isolates from the publications was *Enterobacter* spp. followed by *Citrobacter* spp. (50%), *Klebsiella* spp. (46%) and *Escherichia* spp. (38%) etc.

each. Five food samples (koko, kebab, palm nut soup, red oil and akple/banku) contained two bacterial species each. One sample (waakye) had five bacteria species, while macaroni had the highest number (16) of bacteria species isolates (Table 2).

Discussion

The small amount of microbial food safety research in Ghana calls for concern because of the increasing population and increasing consumer interest. We found that the number of microbial food safety articles is abysmal (Table 1). It is possible that some microbial food safety research papers that are not in PubMed might not have been included in this study, but PubMed contains most of the scientific work worldwide. The analysis performed here suggests that researchers (both governmental and private based) should take into consideration the paucity of food safety research, especially in the northern regions of Ghana and support this research field (Figure 1). Ensuring basic food safety principles is very important if the problem of food-borne illness is to be reduced, to decrease the government's huge expenditure on food-borne illnesses as stated by the Food and Agriculture Organization (FAO) [22]. The regions in the north of Ghana have fewer resources, the majority of its people are poor [23], and the region has a high incidence of disease compared to the South. Poverty is known to have a direct influence on health in Ghana [24].

Most of the articles in our study involved one intervention. Almost less than half of the articles detected multiple bacterial species in their studies, although three did not describe the pathogen type. Most of the publications seemed to pay more attention to the microbial contamination resulting from post-processing of food, *e.g.* street food, with less focus on contamination occurring during the processing and primary production (farm) stages. As an alternative, we would recommend the monitoring of food from farm to fork, which has been found to be very effective in producing safer food devoid of microorganisms [7]. One impressive study, which did not qualify for inclusion in our meta-analysis, assessed the effect of applying Good Management Practices and the Hazard Analysis and Critical Control Points (HACCP) to traditional food processing at a semi-commercial kenkey production plant in Ghana [25]. We urge researchers to investigate more traditional foods, which may have a high risk of microbial contamination, to give directions on how to manage the microbial hazards associated with them. None of the publications included seafood, shellfish or aqua-cultural products in their studies. This omission calls for concern considering the number of people who consume fish; it is recognized that fish is the most important source of animal protein in Ghana [26]. One major food group that was missing in all the publications studied was fruit. We believe that fruit represents a high-risk food to consumers because they

Table 3. Criteria for the methodological soundness of the 11 articles involved in the meta-analysis addressing microbial food safety interventions published between 1997-2009

Criteria	Articles specific to one intervention (n = 7)	Articles specific to multiple interventions (n = 2)	General articles with a section on intervention (n = 2)
The article addressed a focused intervention question	6	2	2
The method of locating evidence was described	7	2	2
Explicit criteria was used to select studies	5	2	1
The methodological quality of the primary studies was assessed	7	2	2
Assessment of the study was reproducible	7	2	2
Quantitative summary of the intervention effectiveness among studies was presented	5	2	2
Possible reasons for the difference between studies were presented	5	2	1
The generalizability of the result to target group was discussed	6	2	2
Directions for future research were proposed	1	1	0
Outcomes included the pathogen of interest within the food production sector	6	1	1

are eaten without heating and are generally not handled hygienically. Research into the microbiological quality of street-sold bread may provide useful information on the safety of bread since it is one of the most common street foods and poorly handled, especially in the hinterlands.

The potential impact of the presence of the microorganisms isolated from various food samples cannot be appropriately evaluated without testing them against the common antibiotics used in the area. Additional information concerning the antimicrobial resistance levels of the isolates could help policy makers and other researchers in the country, as well as inform the global fight against antimicrobial resistance. While financial constraints or inadequate access to resources may be factors when considering additional parameters in a study, researchers concerned with microbial food safety in Ghana should try as much as possible to consider antibiotic susceptibility testing in their studies whenever they succeed in the isolation and identification of microorganisms from food isolates. We would recommend that this be performed retrospectively if the isolates described in these articles are preserved in archives. Few proven molecular mechanisms for antimicrobial resistance control exist in Africa [27]. Based on the results of this study, we recommend that researchers consider isolating the most dominant isolates (Figure 2) from food to obtain information about the levels of resistance to antimicrobials of microorganisms found in food in Ghana. The European Union is currently searching for ways to overcome the problem of antimicrobial resistance within its member countries against some of the common microbes found in Ghanaian foods, such as *Klebsiella pneumoniae, Escherichia coli* and *Pseudomonas aeruginosa.* The recent *E. coli* outbreak in Germany, a food-borne antimicrobial resistant clone, is an example of the seriousness of the problem [9].

One article in our study reported that food handlers constitute a significant risk in the spread of enteric fever in Kumasi [18]. This observation calls for concern because the situation could be worse in other towns where food safety education is generally lacking. A nation-wide food safety education campaign using the World Health Organization's (WHO) five basic keys [28] to ensuring safer food can help to update practices of new and established food vendors. The prevalence of fecal contamination indicator microorganisms (*E. coli*) in food must be considered threatening. Food vendors in the country should be obliged by law to undergo regular examinations before handling food sold to the general public. All the municipalities and district assemblies in the country should be encouraged to embrace the

concept of Food Safety Supervisors who must constantly check the food vendors. For effective and efficient enforcement of food safety and food laws, the government should try to merge the Ghana Standards Board and the Ghana Food and Drugs Board, which seem to have duplicate functions in certain areas of their operations.

In one of the articles within the meta-analysis, a strain identified as *Shigella* sp. was isolated from an imported chicken (Table 2), but this isolate was absent from local chickens. Contaminated imported chicken must be treated as an urgent problem, as Ghana is a food-deficient country and imports a much of its food. More than 200 known diseases are transmitted through food [6], and this fact underscores the necessity to strengthen the surveillance of food and food products entering the country to prevent or minimize the inflow of possible infection.

All the articles studied used classical methods in the identification of bacteria. None of the articles employed molecular methods of bacterial isolation and identification, which can give more accurate results. The methodological quality of the primary studies did not cover a wide scope, probably because of financial constraints. Six of the articles did not indicate the Total Viable Counts of the isolates in food. The inclusion of the total count or enumeration of colony forming units (cfu/ml) can improve the reproducibility of the studies by serving as a guide for future researchers and helping to determine the acceptable levels of contamination. Most (9) of the articles did not propose a direction for future research (Table 3), which can be useful for identifying areas where research is lacking and may discourage the duplication of research efforts [29]. Eight of the articles included some pathogens of interest in the food production sector, but only a few included bacteria that are potentially pathogenic to the consumer (*Campylobacter* spp., *Salmonella* spp., *Bacillus* spp., etc.). The isolation of other important food-borne pathogens such as *Listeria monocytogenes*/*Listeria* spp., *Clostridium perfringens*, *Cronobacter* spp. and *Escherichia coli O157:H7* were not considered in any of the studies. This omission hinders the development of specific interventions for the elimination of microorganisms in the food chain since some species require special treatments to be eradicated.

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