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Review

Prevalence of foodborne pathogens in food from selected African countries – A meta-analysis

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ABSTRACT

Food safety information in the African region is insufficient and fragmented due to lack of surveillance, documentation and reporting, thereby resulting in inefficient utilization of resources, duplication of activities, and lack of synergy among the countries of the region. This paper reviews the prevalence of foodborne pathogens in seven African countries (Benin, Botswana, Ghana, Kenya, Nigeria, Sudan and Uganda) from papers in regional or international journals published between January 2000 and December 2015. One hundred and sixteen publications that dealt with food microbiology were reviewed for general analysis, while 66 papers on contamination of pathogenic bacteria were used for meta-analysis of prevalence. The food items were split into two categories: raw foods and ready-to-eat (RTE) foods (including street food and beverages) for meta-analysis. Majority of the reviewed studies (67.2%, 78/116) dealt with food of animal origin: 38.8% for meat and eggs, 17.2% for dairy products and 11.2% for aquatic products. Only 8.6% examined foods of plant origin (fruits and vegetables). The remaining 24.1% was the composite RTE food and beverages. *Enterobacteriaceae*, *Escherichia coli*, *Salmonella*, *Staphylococcus aureus* and *Listeria monocytogenes* were the most frequently reported organisms in those studies. Although the data were highly heterogeneous, a striking feature is high prevalence of the major pathogens in RTE foods, almost as high as in raw foods. *E. coli* averaged at 37.6% in raw foods and 31.6% in RTE foods. The corresponding prevalence for *Salmonella* was 19.9% *vs* 21.7%; *S. aureus*, 27.8% *vs* 25.1% and *L. monocytogenes*, 19.5% *vs* 6.7%. The average prevalence of foodborne pathogens in these countries was 34.2% (29.0–39.3%). Differences in food types as well as non-uniform protocols for sampling and identification might have contributed to high heterogeneity ($I^2 > 97\%$) although some high prevalence data could be factual with extensive varieties of raw and RTE foods. Need for improved hygienic practices in handling of raw or RTE foods are suggested. Implementation of surveillance programs that use uniform laboratory protocols across the region could give homogeneous results.

Contents

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1. Introduction

While developing countries continue to struggle with the issue of food security, that is, the amount of food enough for consumption by the growing population; there is yet another quandary in these countries: the safety of food. It is estimated that over 200 types of diseases are caused or spread by food, sometimes causing long-term health problems in vulnerable groups of people such as the elderly, pregnant and the infants (WHO, 2015). Thus, ensuring the safety of food is an important challenge in developing countries from the public health perspective.

The WHO, in collaboration with African countries, in 1998 initiated "Integrated Disease Surveillance & Response" (IDSR) in the region focusing on a list of priority diseases including cholera and diarrheal diseases in children under five (WHO/AFRO, World Health Organization Regional Office for Africa, 2013). It was only after 2005 when International Health Regulations (IHR) came into existence that ISDR was obliged to include outbreaks of contaminated food and foodborne diseases under the reporting system (Mensah et al., 2012). In spite of this effort, food safety programs in the African region remain fragmented, thereby resulting in inefficient utilization of resources, duplication of activities, and lack of synergy among the countries and stakeholders of the region. This, in turn, has led to paucity of data on outbreaks of foodborne illness in the African continent (Akhtar et al., 2014). A typical example of this scantiness is that out of 33 African countries registered to report the national foodborne diseases data to Global Food Network databank; only 11 countries had submitted their data as of 2012 with just one country being a regular reporter (Mensah et al., 2012).

As a result of improving economy, there is an emergence of a consumer class in African countries, who are now able to direct more than half of their income towards discretionary spending (Lund & Wamelen, 2012). A common example of such discretionary expense is the expenditure on street foods as such foods are ready-made, easily available, affordable and freshly prepared. However, the street foods may jeopardize human health due to the risk of foodborne contaminants. Poor sanitation, improper personal hygiene and contaminated utensils as well as untreated water used by street vendors in developing countries, all act as a conduit for transmission of pathogens via foods to humans (Onyeneho and Hedberg, 2013). There are several studies on the levels of food contamination and prevalence of food transmitted pathogens in meat, milk or fish for African countries (Manani et al., 2006; Kombat et al., 2013; Kpodekon et al., 2013; Ndahi et al., 2014) and the prevalence data varies greatly across studies.

This review was attempted to generate pooled prevalence data based on existing publications from selected African countries using the meta-analytical approach. The main objectives were to estimate the prevalence of foodborne pathogens in African food systems, to assess the differences of such prevalence between raw and ready to eat (RTE) foods and among countries, and to evaluate the level of heterogeneity of the published prevalence data.

2. Methods

2.1. Study region, literature search and eligibility criteria

This study was carried out as a review of the available publications from seven selected African countries viz. Benin, Botswana, Ghana, Kenya, Nigeria, Sudan and Uganda. Collaborating authors collected publications from their respective countries. The publications included those available either within the country at local institutions or in global databases. Search was also performed on the African Journals Online (AJOL) database as well as PubMed database, using the terms 'food safety', 'food microbiology', 'food pathogens' and 'country name' as the string of keywords to collect additional publications dated between January 2000 to December 2015. These were tallied with the ones received from the collaborators and screened as per the inclusion-exclusion criteria listed below. A record was maintained of the entire literature search process.

Publications were excluded if they (Akhtar et al., 2014) had sample number of <30; (Breurec et al., 2010) were related to investigation of knowledge, attitude and practice (KAP), risk factors and value chain; (Higgins et al., 2003) dealt with food handlers and their hygienic practices; (Kagambega et al., 2011) examined vectors involved in microbial transmission, such as flies, cockroaches, and other fomites; (Kagambega et al., 2013) performed economic analyses of foodborne diseases and technological reviews; (Kleter & Marvin, 2009) were related to cooking practices and food handling procedures; (Knutsson et al., 2011) were related to case studies of food-poisoning with unknown etiologies; (Kokkinos et al., 2012) examined the veterinary drugs, toxins, pesticide, metals, and other residues in the food components; (Kombat et al., 2013) were related to food processing, nutrient composition and proximate analyses; (Kpodekon et al., 2013) focused on effects of heat, chemical, dehydration or other physical agents on the quality & shelf-life of foods; and (Lund & Wamelen, 2012) focused on the use of photochemical in food industry.

Endnote version X6 (Thomson Reuters) was used to catalogue, collate and manage the collected publications and citations thereafter.

2.2. Data extraction

Full text of screened publications was obtained from appropriate sources and data extracted in a MS Excel spreadsheet under multiple headings such as food commodity, sample size, sampling point, method of analyses used, organisms isolated, prevalence and other tests performed on the isolates.

2.3. Data analysis

The extracted data were used for descriptive statistics. Further analysis was carried out in multiple steps. The meta-analysis and Forest plotting of major pathogens as well as estimation of the country effect were done using the Open Meta-Analyst, Task Order # 2 software (available at https://www.brown.edu/academics/public-health/

research/evidence-based-medicine/research-initiatives/software-0). The data were analysed in binary random model effects by the DerSimonian-Laird method at 95% confidence interval. Individual models were used for analysis of the each major pathogen. The food category as raw or RTE was used as covariate for subgroup meta-analysis for each pathogen. Because the types of food were so diverse and the number of studies dealing with the prevalence of a particular pathogen in a specific food type was low among the total 'eligible' studies, we did not try to consider specific food type as a co-variable. The variations among countries were estimated using a country name as a covariate for the subgroup. Inconsistency (or heterogeneity) across the studies estimated in the random-effects model was quantified using inverse variance index (I^2). The I^2 values at 25%, 50% and 75% were considered as low, moderate and high heterogeneity, respectively (Higgins et al., 2003).

3. Results

Among the 226 publications collected by the collaborators from listed countries, eighty publications were considered suitable for inclusion in this review. Inclusion of additional publications available from PubMed and AJOL databases finally summed up to 116 publications that specifically dealt with food safety, food microbiology and food pathogens. The flow diagram of the literature search and selection of eligible studies is presented in Fig. 1.

3.1. Papers included in the analysis by countries and types of commodities examined

Table 1 shows the number of publications from individual countries that were included in this review. Ghana, Sudan and Nigeria had more papers included (n = 21 to 24) than the other countries. There were only 8 papers from Uganda. Kenya, Benin and Botswana ranged in-between.

Table 1
Number of publications reviewed by country.

Country	Number of publications	References[a]
Benin	12	24, 25, 30, 32, 37, 45, 56, 62, 63, 72, 103, 105
Botswana	11	1, 35, 66, 68, 71, 74, 79, 80, 84, 99, 106
Ghana	24	2, 6, 7, 10, 11, 12, 13, 14, 15, 20, 21, 22, 23, 26, 28, 38, 46, 65, 69, 75, 91, 92, 111, 116
Kenya	18	27, 48, 49, 50, 57, 59, 60, 61, 64, 67, 70, 73, 88, 93, 94, 97, 102, 108
Nigeria	21	5, 8, 34, 36, 39, 43, 44, 47, 54, 55, 87, 89, 95, 96, 98, 100, 101, 104, 107, 110, 114
Sudan	22	3, 4, 9, 16, 17, 18, 19, 29, 40, 41, 42, 51, 53, 76, 77, 78, 85, 90, 105, 112, 113, 115
Uganda	8	31, 33, 52, 58, 81, 82, 83, 86
Total	116	

[a] The number corresponds to the serial number of reviewed publications listed out in 'Data in Brief'.

The food commodities varied in terms of their origin, type, utility or value addition. For the purpose of analyses, we grouped these items under a broader range of commodities as shown in Table 2. Majority of the studies (67.2%, 78/116) dealt with foods, raw or ready-to-eat (RTE) of animal origin: 38.8% (45/116) meat, 17.2% (20/116) dairy products, and 11.2% (13/116) aquatic products. Only 8.6% (10/116) of the foods examined were of plant origin. The remaining 24.1% (28/116) were the RTE composite foods, menu items of mixed origin, and beverages such as drinking water (bottled, sachet, spring water, well

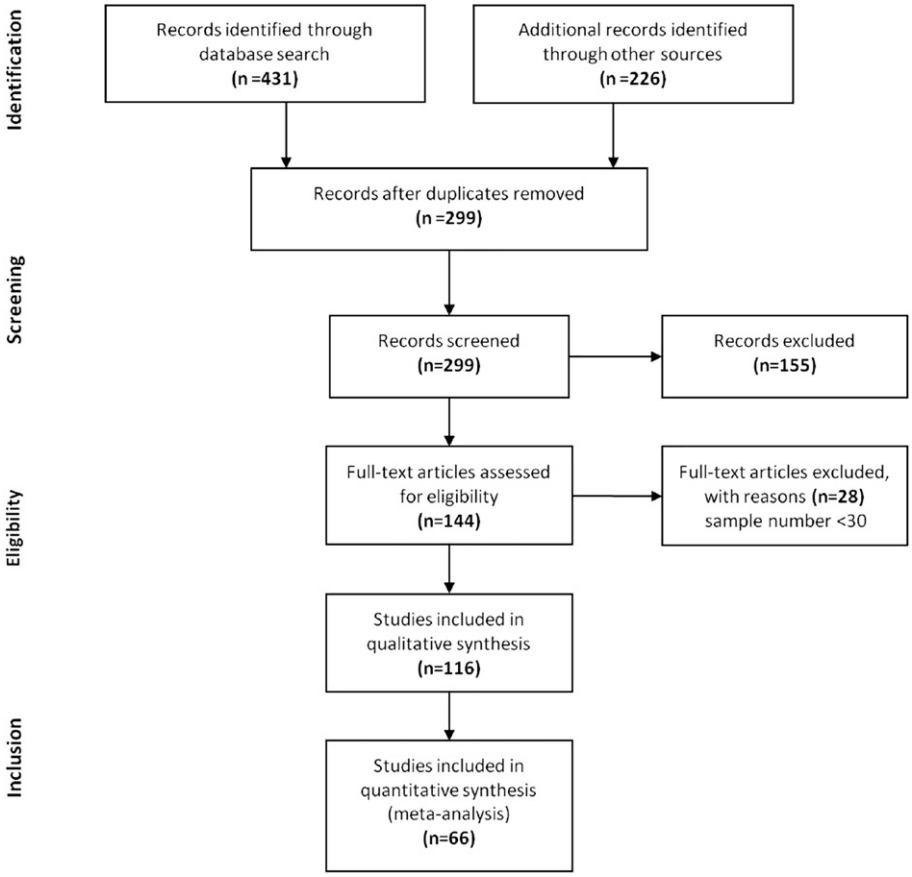


Fig. 1. Flow diagram of the literature search and selection of eligible studies.

Table 2
Food commodities covered in the publications.

Commodity	Includes	Number of publications
Meat	Fresh meat, frozen meat, ready-to-eat meat & meat products (sausages, burgers etc), value added meat items (dried, smoked, pickled, fermented etc), body swabs from slaughtered animals, factories, and slaughter tools	45
Dairy products	Fresh milk (pasteurized or non pasteurized), milk products (ice-cream, cheese etc), value added milk items (fermented milk) & water used in dairy products	20
Aquatic foods	Fish (fresh or frozen), snails, clams, value added fish (dried, fermented, smoked, pickled) & fish body swabs	13
Vegetables, fruits & juices	All types of vegetables (raw or frozen or cooked), all fruits & juices (fresh or processed), water used in vegetable market & salads	10
Ready-to-eat foods and others[a]	Drinking water, mixed foods served at streets, hospital and airports, mixed non-specific food items, mushrooms, spices and condiments.	28
Total		116

[a] The ready-to eat foods include the composite menu items from street vendors, restaurants and local eateries, while others include cereals, pickles, sauces, dips and beverages like gruels and soups.

water, bore-hole water), gruels, soups and some dipping pickles/sauces that were sold as compliments to certain RTE food items.

3.2. Organisms recovered by types of food commodity

Table 3 shows the recovery of microorganisms *Escherichia coli*, *Staphylococcus aureus*, *Salmonella*, *Bacillus* and *Listeria monocytogenes* in the foods. Most of them appeared in meat. Since most of the studies reported multiple organisms in a single food commodity, the total number of major organisms reported (n = 201) was higher than the total number of studies (n = 116). This should not be regarded as a discrepancy. Other microorganisms reported in these publications were *Campylobacter*, *Streptococcus*, *Pseudomonas*, *Clostridium*, *Yersinia*, *Enterococcus*, and *Vibrio*, most of which were identified only up to the genus level.

3.3. Prevalence of pathogens in raw foods and ready-to-eat food products

There were several studies that focused on the sentinel organisms of general hygiene, such as fecal coliforms, *Enterobacteriaceae*, *Micrococcus* spp., etc. As these studies dealt with general hygiene such as quantity of bacterial populations in food in terms of colony forming unit (CFU) or most probable number (MPN), they (n = 50) were not included for further analysis. A total of 66 papers were subjected to meta-analysis. These papers dealt with prevalence of foodborne pathogenic bacteria such as *E. coli* (including VTEC/EHEC/ETEC/STEC or those mentioned as *E. coli* but excluding those reported as coliforms, environmental *E. coli*, thermotolerant coliforms or fecal coliforms), *Salmonella* (with or without indication of species and serotypes), *L. monocytogenes* and *S. aureus*. The publications were classified into two categories, one dealing with 'raw foods' of plant or animal origin and the other with 'ready to eat (RTE) foods' of plant or animal origin. Since some of the studies reported on more than one type of food commodity, a total of 108 different food items (including 68 raw foods and 40 RTE foods) were reported in these 66 publications.

Fig. 2 shows that the average prevalence of *E. coli* in the foods as calculated from the reviewed publications (n = 33) was 35.4% (95% CI: 27.7–43.1, $p < 0.001$). The average prevalence in raw foods was 37.6% (95% CI: 28.1–47.1) (n = 21). RTE foods had average prevalence of 31.6% (95% CI: 15.3–47.9%) (n = 12). There was high heterogeneity among the publications concerning prevalence of *E. coli* in foods (I^2 = 99.7%).

The average prevalence of *Salmonella* spp. in the foods as calculated from 31 publications was 20.5% (95% CI: 13.3–27.7, $p < 0.001$). Prevalence of *Salmonella* averaged at 19.9% (95% CI: 10.6–29.2) (n = 20) in the raw foods and 21.7% (95% CI: 9.8–33.5) (n = 11) in the RTE foods (Fig. 3). There was also high heterogeneity among these publications (I^2 = 99.3%).

Fig. 4 shows the average prevalence of *S. aureus* in the foods at 26.5% (95% CI: 17.3–35.6, $p < 0.001$) (n = 27). The average prevalence of *S. aureus* in raw foods was 27.8% (95% CI: 11.1–44.6) (n = 13) and 25.1% (5% CI: 15.2–35.0) (n = 14) in RTE foods. The reports on this pathogen were also of high heterogeneity (I^2 = 99.1%).

Fig. 5 shows that *L. monocytogenes* had average prevalence of 13.5% (95% CI: 7.1–19.8, $p < 0.001$) (n = 13). Its average prevalence was 19.5% (95% CI: 7.7–31.4%) in the raw foods (n = 7) and 6.7% (95% CI: 2.5–10.8%) in RTE foods (n = 6). *L. monocytogenes* had the lowest prevalence rate as compared to the other three pathogens examined. The heterogeneity among the reports on *L. monocytogenes* was also high (I^2 = 97.8%).

3.4. Prevalence by countries

The overall average prevalence of foodborne pathogens in these countries was 34.2% (95% CI, 29.0–39.3%) and difference in prevalence rates among the countries was statistically significant ($p < 0.001$). Prevalence was highest in Uganda (50.8% with 95% CI between 9.8 and 91.8, $p < 0.015$) and lowest in Botswana (9.1% with 95% CI between 5.5 and 12.8, $p < 0.001$) (Fig. 6). The other five countries had prevalence levels between the two above. The values of I^2 between 94.1% and 99.8% for all countries imply that the studies from these countries had high heterogeneity.

3.5. Sampling plans and methods used in the studies

There were varieties of sampling points in the studies reviewed. The commonest sampling points were those either at the production sites (slaughterhouses, butchers' stalls or farms) or at markets (malls, local markets, farmers' markets and retail outlets) for fresh or raw food commodities. The local food sellers, street vendors, roadside eateries, makeshift shops or restaurants were the common points of sampling for RTE foods. None of the studies used a systemic sampling scheme for a particular food item from production to market along the food chain. There were variations in terms of sample size, sampling frame (criteria for collecting samples, inclusion and exclusion of commodities to be studied), and isolation protocols among the studies even for the same

Table 3
Number of studies showing positive findings of major bacterial species in different foods in the reviewed publications (n = 116).

	Meat	Milk	Fish	Vegs & fruits	Cereals	Others	Total (%)[b]
Eschericia coli	22	8	5	6	1	9	51 (44)
Staphylococcus aureus	22	7	4	3	1	5	42 (36)
Enterobacteriaceae[a]	14	5	5	4	1	10	39 (34)
Salmonella spp.	21	2	5	3	1	4	36 (31)
Bacillus spp.	8	2	1	2	1	4	18 (16)
Listeria monocytogenes	6	3	1	4	1	0	15 (13)
Total							201

[a] *Enterobacteriaceae* does not include pathogenic *E. coli* and *Salmonella*.
[b] Since most studies have reported multiple organisms from a single food commodity, the total number of isolates (n = 201) is higher than the number of publications reviewed (n = 116). The percentage (%) recorded is the addition of all the counts or numbers of the particular pathogen in foods in all the publications reviewed divided by the total number of studies (116) multiplied by 100.

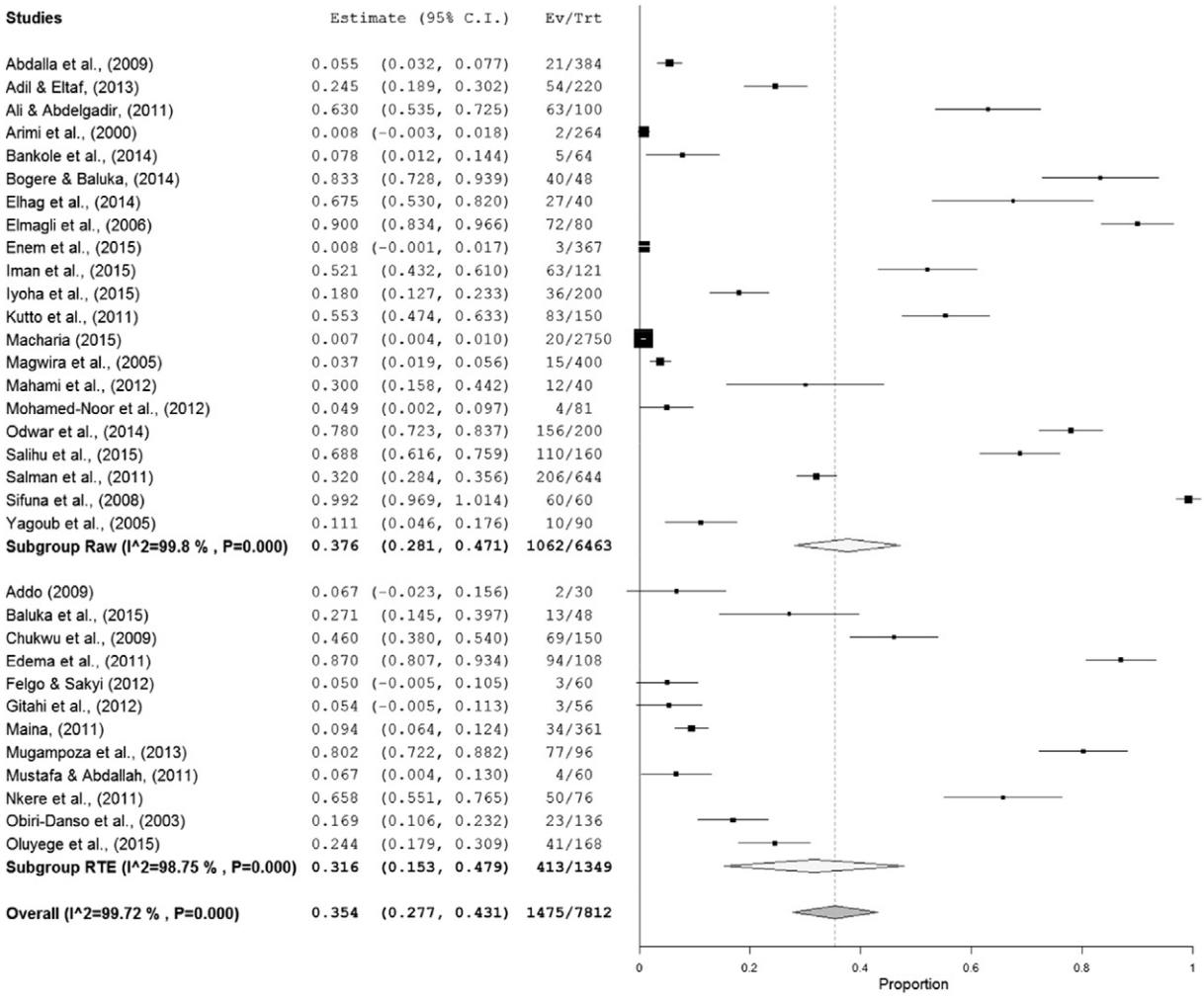


Fig. 2. Prevalence of *E. coli* (including ETEC, VTEC, STEC, EHEC) in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.050$, $I^2 = 99.72\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, with the range of proportion in 95% confidence interval (CI). Studies given higher weights are indicated by larger markers.

microorganism. Few studies used nationally or internationally accredited methods. There was no uniformity among the studies with regards to the protocol for isolation and identification.

All the studies used conventional microbiological methods for bacterial isolation and identification. Eighteen publications (15.5%) combined conventional microbiology with molecular methods, while nine (7.8%) combined conventional microbiology with serological tools for bacterial identification.

4. Discussion

Seven countries of different developmental and economic status in Africa were chosen, so expecting a similar level of scientific advancement and sophistication in terms of research output and methodology is impractical. Moreover, it has been reported that research production in Africa is highly skewed (Uthman & Uthman, 2007) as South Africa alone contributed to one third of the African researches indexed in international databases like PubMed. Other one third was the cumulative contribution of Egypt and Nigeria while the remaining one third was the contribution of all other African countries. Six out of the seven countries in our selection were grouped in the last one-third segment. Some 65% of African research papers were published in local journals that are not listed in the international databases as PubMed and Scopus (Uthman & Uthman, 2007), while some are available as grey literatures or as hard copies only in university repositories and libraries. This might account for the retrieval of fewer literatures for some countries in this review.

Of the 116 publications reviewed, for the 15-year period from 2000, nearly 70% covered the period between 2010 and 2015. This indicates, in part, increased attention to the issues of microbial food safety in this region in recent years. The research input also varied among the countries, with Ghana, Nigeria and Sudan being more active with higher number of publications per country included in this review. In global context, three major foodborne bacterial pathogens (*Salmonella* spp., *Campylobacter* spp. and *E. coli*) have persisted throughout the 1990s to date with relatively more recent addition of L. *monocytogenes* (Newell et al., 2010). This review concludes that the most common microorganisms isolated from selected African countries were *E. coli*, *Salmonella* spp., *S. aureus*, and *L. monocytogenes*, all having two-digit percent prevalence on average, both in raw and in RTE foods. Higher prevalence rates of *E. coli* and *Salmonella* in raw and RTE foods suggest a significant breach in the critical control points during handling of foods.

Several recent reports from other African countries (not included in this review) showed varying rates of prevalence of foodborne pathogens. Prevalence of *Salmonella* spp. was 53% in slaughtered animals in Burkina Faso (Kagambega et al., 2013). Another study from Burkina Faso reported 100% prevalence of *E. coli* in raw meats, but only 9.3% for *Salmonella* (Kagambega et al., 2011). A study in Lesotho reported

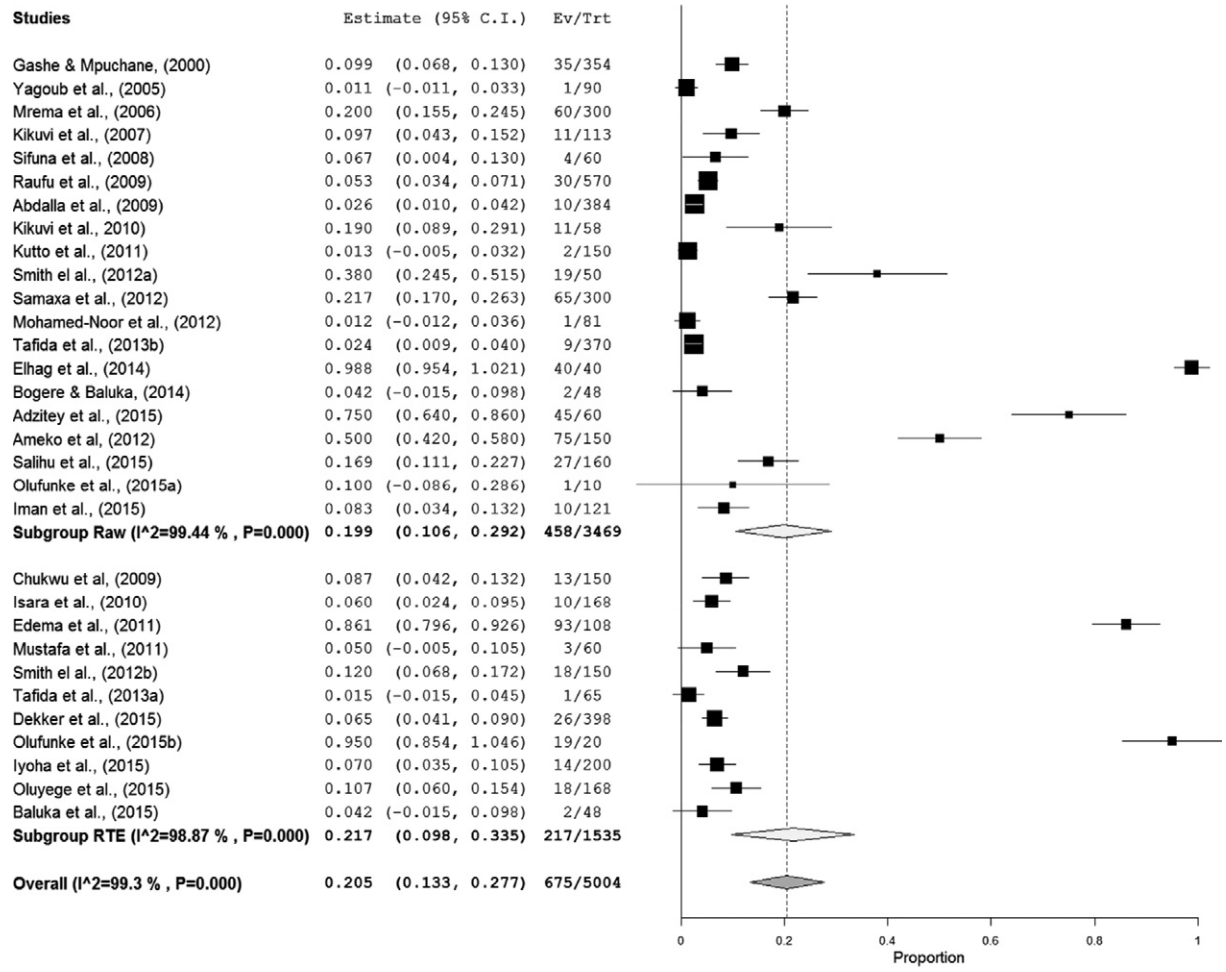


Fig. 3. Prevalence of *Salmonella* in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.041$, $I^2 = 99.3\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, with the range of proportion in 95% confidence interval (CI). Studies given higher weights are indicated by larger markers.

the prevalence of *E. coli*, *Staphylococcus* and *Salmonella* at 5.41%, 4.33% and 0.72%, respectively (Seeiso and McCrindle, 2009). Estimation of the country effect on average prevalence revealed that the findings from all studies in these countries were highly heterogeneous, as shown by scattered points with apparent outliers in Fig. 6. The prevalence data were also of high heterogeneity among studies. It is difficult to identify the specific factors that might have contributed to high heterogeneity of the data. The prevalence data could be factual with extensive varieties of foods processed or handled under different hygienic conditions.

Various global studies strongly adhere to the fact that most of the foodborne pathogens are introduced as exogenous contaminants during handling, processing and preparation rather than being present as endogenous contaminants (Rane, 2011). Presence of *E. coli* is considered as a reliable marker of fecal contamination (Akhtar et al., 2014). For crops that are grown on soil which has been fertilized with animal dung or poultry manure, a practice common to Africa or Asia (Shenge et al., 2015), or fields irrigated with grey water (Madungwe and Sakuringwa, 2007), there will be higher risk of the final produce being contaminated by organisms such as *E. coli*, *Salmonella* and various *Enterobacteriaceae* (Newell et al., 2010). Recent studies on contamination of microbial pathogens along the value chain for vegetables in Nairobi have shown that the risk of contamination is greater during postharvest activities rather than during their production using sewage irrigation water (Samuel K. Mabuga, personal communication). Similarly there are reports on presence of *Listeria* in milk produced from healthy animal as a result of exogenous contamination (Breurec et al., 2010). This might be a possible reason that most of the *L. monocytogenes* were recovered from raw milk or ready to eat milk products like cheese and yoghurts. All these indicate that post-production processes are likely to contaminate the food products, either raw or RTE.

This review reveals that pooled average prevalence of these four pathogens in RTE foods are in the range to raw foods. In addition to poor general hygiene, the sanitary status of raw materials, the quality of water used during cleaning-cooking procedure, mode of cooking/food preparation (e.g. insufficient heat treatment) and subsequent holding of foods in absence of refrigeration or human intervention could greatly contribute to prevalence of these pathogens in RTE foods. All RTE food commodities in these studies were sampled from roadside vendors, local caterers, makeshift shops and restaurants with minimal facilities and poor hygiene that might have led to higher contamination rates. An African survey reported that 85% of the vendors prepared foods like fish, fruit salads, roasted maize and chips in unhygienic conditions with garbage and waste in the vicinity which provided harborage for vectors (e.g. flies) that might be linked to enteric diseases caused by *Shigella*, *Salmonella* and *E. coli* (Rane, 2011).

There was a report in 2002, an early year within the period 2000–2015 for this review, on the need to improve the hygienic status of street vendors in terms of their service environment, practices and

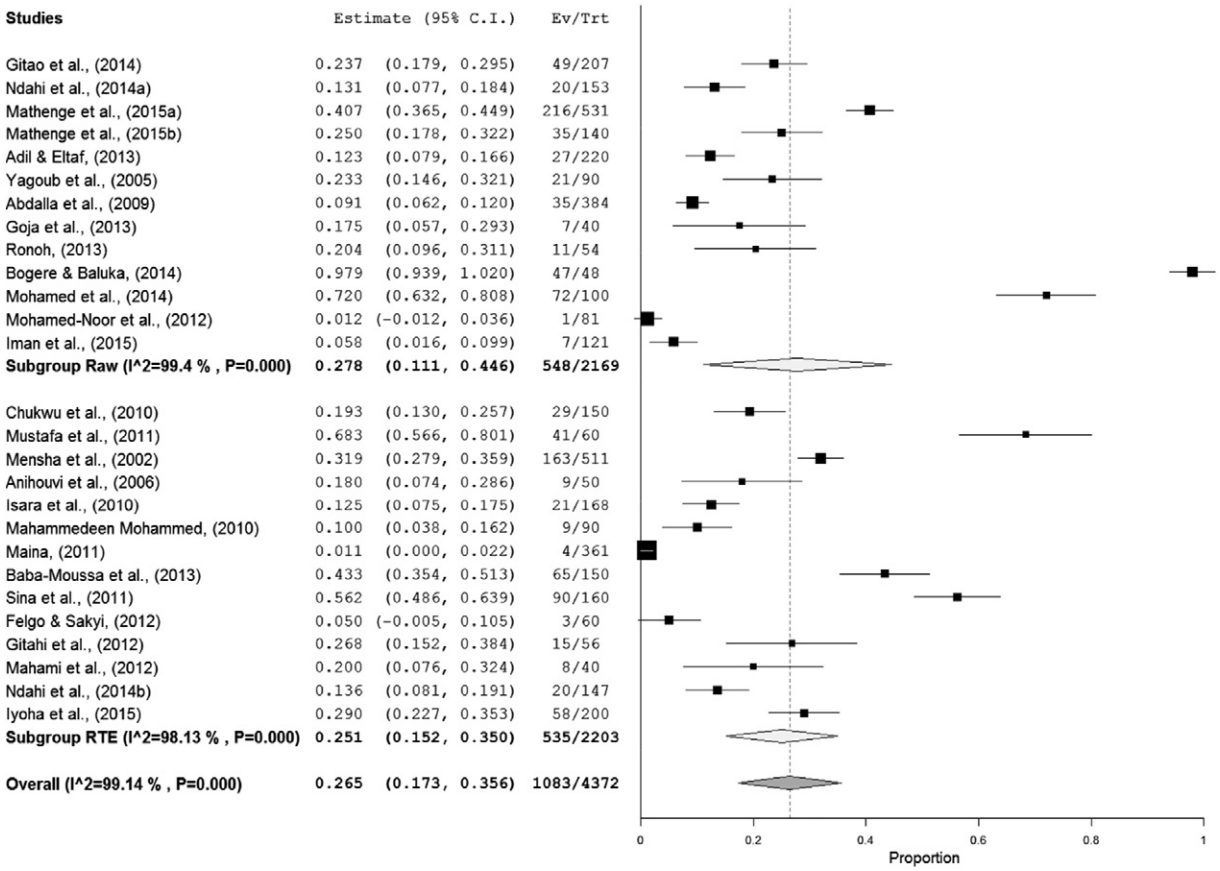


Fig. 4. Prevalence of *Staphylococcus aureus* in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.057$, $I^2 = 99.14\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, with the range of proportion in 95% confidence interval (CI). Studies given higher weights are indicated by larger markers.

personal behavior (Mensah et al. 2002). However, it is evident that those recommendations have not been implemented as suggested. High levels of *E. coli* in raw and RTE food commodities are clear indication of poor hygiene and sanitation (Manguiat and Fang, 2013). Presence of *S. aureus*, which is regarded as an indicator organism for contamination from human hands or improper handling of

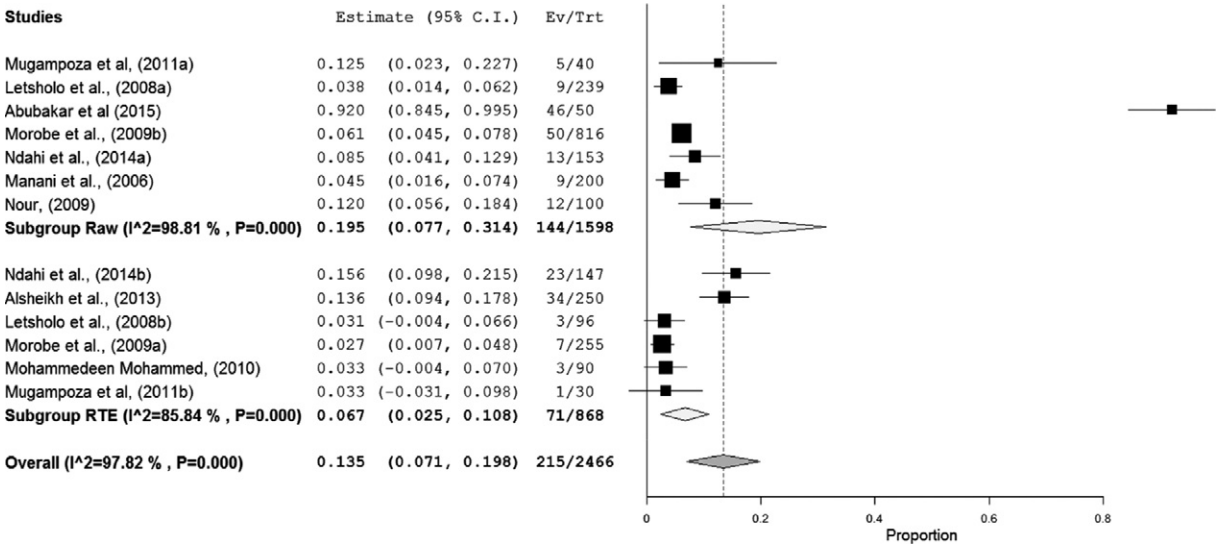
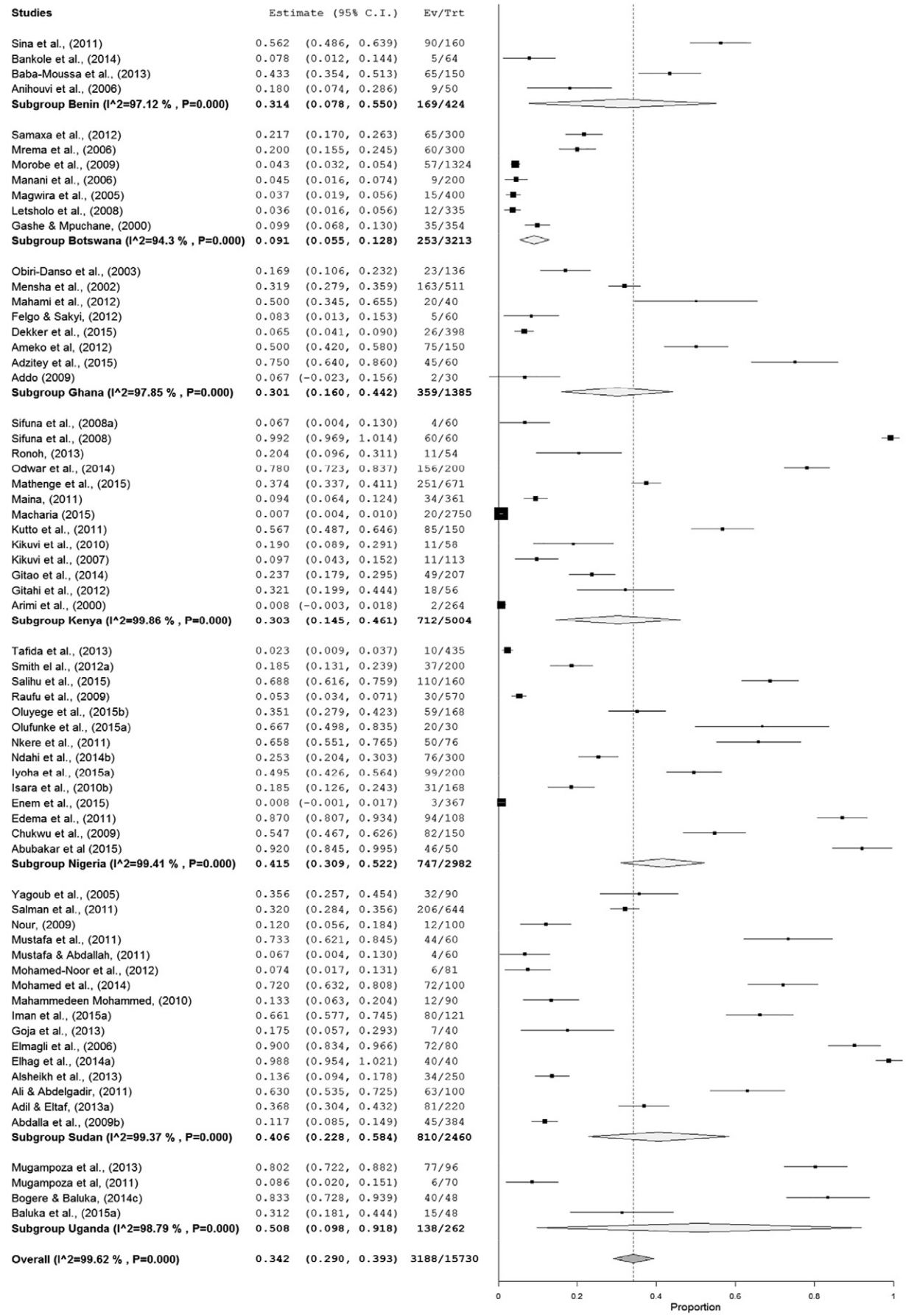


Fig. 5. Prevalence of *Listeria monocytogenes* in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.013$, $I^2 = 97.82\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, with the range of proportion in 95% confidence interval (CI). Studies given higher weights are indicated by larger markers.


Studies
Estimate (95% C.I.)
Ev/Trt
Sina et al., (2011) 0.562 (0.486, 0.639) 90/160
Bankole et al., (2014) 0.078 (0.012, 0.144) 5/64
Baba-Moussa et al., (2013) 0.433 (0.354, 0.513) 65/150
Anihouvi et al., (2006) 0.180 (0.074, 0.286) 9/50
Subgroup Benin (I^2=97.12 % , P=0.000) 0.314 (0.078, 0.550) 169/424
Samaxa et al., (2012) 0.217 (0.170, 0.263) 65/300
Mrema et al., (2006) 0.200 (0.155, 0.245) 60/300
Morobe et al., (2009) 0.043 (0.032, 0.054) 57/1324
Manani et al., (2006) 0.045 (0.016, 0.074) 9/200
Magwira et al., (2005) 0.037 (0.019, 0.056) 15/400
Letsholo et al., (2008) 0.036 (0.016, 0.056) 12/335
Gashe & Mpuchane, (2000) 0.099 (0.068, 0.130) 35/354
Subgroup Botswana (I^2=94.3 % , P=0.000) 0.091 (0.055, 0.128) 253/3213
Obiri-Danso et al., (2003) 0.169 (0.106, 0.232) 23/136
Mensha et al., (2002) 0.319 (0.279, 0.359) 163/511
Mahami et al., (2012) 0.500 (0.345, 0.655) 20/40
Felgo & Sakyi, (2012) 0.083 (0.013, 0.153) 5/60
Dekker et al., (2015) 0.065 (0.041, 0.090) 26/398
Ameko et al, (2012) 0.500 (0.420, 0.580) 75/150
Adzitey et al., (2015) 0.750 (0.640, 0.860) 45/60
Addo (2009) 0.067 (-0.023, 0.156) 2/30
Subgroup Ghana (I^2=97.85 % , P=0.000) 0.301 (0.160, 0.442) 359/1385
Sifuna et al., (2008a) 0.067 (0.004, 0.130) 4/60
Sifuna et al., (2008) 0.992 (0.969, 1.014) 60/60
Ronoh, (2013) 0.204 (0.096, 0.311) 11/54
Odwar et al., (2014) 0.780 (0.723, 0.837) 156/200
Mathenge et al., (2015) 0.374 (0.337, 0.411) 251/671
Maina, (2011) 0.094 (0.064, 0.124) 34/361
Macharia (2015) 0.007 (0.004, 0.010) 20/2750
Kutto et al., (2011) 0.567 (0.487, 0.646) 85/150
Kikuvi et al., (2010) 0.190 (0.089, 0.291) 11/58
Kikuvi et al., (2007) 0.097 (0.043, 0.152) 11/113
Gitao et al., (2014) 0.237 (0.179, 0.295) 49/207
Gitahi et al., (2012) 0.321 (0.199, 0.444) 18/56
Arimi et al., (2000) 0.008 (-0.003, 0.018) 2/264
Subgroup Kenya (I^2=99.86 % , P=0.000) 0.303 (0.145, 0.461) 712/5004
Tafida et al., (2013) 0.023 (0.009, 0.037) 10/435
Smith el al., (2012a) 0.185 (0.131, 0.239) 37/200
Salihu et al., (2015) 0.688 (0.616, 0.759) 110/160
Raufu et al., (2009) 0.053 (0.034, 0.071) 30/570
Oluyege et al., (2015b) 0.351 (0.279, 0.423) 59/168
Olufunke et al., (2015a) 0.667 (0.498, 0.835) 20/30
Nkere et al., (2011) 0.658 (0.551, 0.765) 50/76
Ndahi et al., (2014b) 0.253 (0.204, 0.303) 76/300
Iyoha et al., (2015a) 0.495 (0.426, 0.564) 99/200
Isara et al., (2010b) 0.185 (0.126, 0.243) 31/168
Enem et al., (2015) 0.008 (-0.001, 0.017) 3/367
Edema et al., (2011) 0.870 (0.807, 0.934) 94/108
Chukwu et al., (2009) 0.547 (0.467, 0.626) 82/150
Abubakar et al (2015) 0.920 (0.845, 0.995) 46/50
Subgroup Nigeria (I^2=99.41 % , P=0.000) 0.415 (0.309, 0.522) 747/2982
Yagoub et al., (2005) 0.356 (0.257, 0.454) 32/90
Salman et al., (2011) 0.320 (0.284, 0.356) 206/644
Nour, (2009) 0.120 (0.056, 0.184) 12/100
Mustafa et al., (2011) 0.733 (0.621, 0.845) 44/60
Mustafa & Abdallah, (2011) 0.067 (0.004, 0.130) 4/60
Mohamed-Noor et al., (2012) 0.074 (0.017, 0.131) 6/81
Mohamed et al., (2014) 0.720 (0.632, 0.808) 72/100
Mahammedeen Mohammed, (2010) 0.133 (0.063, 0.204) 12/90
Iman et al., (2015a) 0.661 (0.577, 0.745) 80/121
Goja et al., (2013) 0.175 (0.057, 0.293) 7/40
Elmagli et al., (2006) 0.900 (0.834, 0.966) 72/80
Elhag et al., (2014a) 0.988 (0.954, 1.021) 40/40
Alsheikh et al., (2013) 0.136 (0.094, 0.178) 34/250
Ali & Abdelgadir, (2011) 0.630 (0.535, 0.725) 63/100
Adil & Eltaf, (2013a) 0.368 (0.304, 0.432) 81/220
Abdalla et al., (2009b) 0.117 (0.085, 0.149) 45/384
Subgroup Sudan (I^2=99.37 % , P=0.000) 0.406 (0.228, 0.584) 810/2460
Mugampoza et al., (2013) 0.802 (0.722, 0.882) 77/96
Mugampoza et al, (2011) 0.086 (0.020, 0.151) 6/70
Bogere & Baluka, (2014c) 0.833 (0.728, 0.939) 40/48
Baluka et al., (2015a) 0.312 (0.181, 0.444) 15/48
Subgroup Uganda (I^2=98.79 % , P=0.000) 0.508 (0.098, 0.918) 138/262
Overall (I^2=99.62 % , P=0.000) 0.342 (0.290, 0.393) 3188/15730
0
0.2
0.4
0.6
0.8
1
Proportion

food (Manguiat & Fang, 2013), also correlates with unhygienic hand practices by the vendors. These scenarios strongly corroborate the assumptions that contamination of foods either originate from the raw food materials or are due to poor personal hygiene and cross-contamination of pathogens from raw foods to RTE foods which could then be aggravated by unclean environment or sometimes even by cross handling of cash in trading of street foods (Muyanja et al., 2011).

The recovery rates of the organisms under study could be severely affected by the methods or protocols used by different laboratories (Kleter and Marvin, 2009). Laboratory protocols used varied among the publications reviewed and only few of the studies used internationally recommended methods and protocols. Sample size is yet another factor in providing data of statistical confidence. Large-scale data with enough number of samples and long-time surveillance increases the sensitivity of the tests. Our literature search did not find any reports of such extensive investigations for these selected African countries. For this reason, twenty-eight studies were excluded from this review because of their small sample size. It is hoped that national and regional surveillance programs for foodborne pathogens using regionally or internationally recognized testing protocols be used in the future. Efforts should be made to integrate resources for research and regulatory activities in food safety management at national or regional level within the African continent for apparent economic reason.

It is widely accepted that safe food can only be assured by preventive measures applied in the entire food chain (Knutsson et al., 2011; Kokkinos et al., 2012; Opiyo et al., 2013). In studies where samples are collected from one point in the food chain, it is impossible to identify the location causing contamination. We found that majority of the studies targeted on foodborne pathogens were from informal food businesses like street foods and open-air markets. In such food operations, there could be no quality assurance programs, nor were there any hygienic measures in place. Therefore, it is challenging to the authorities as to how the RTE foods and street vended foods produced in the informal sectors should be regulated.

5. Conclusion

The common organisms isolated from foods in selected countries during the 15-year period were, in order from high to low, *E. coli*, *S. aureus*, *Salmonella* spp. and *L. monocytogenes* irrespective of the fact that the prevalence data were of high heterogeneity among studies or among countries. Use of different protocols or analytical methods by individual researchers could have contributed to variations among the studies. A distinct feature was that the prevalence of pathogens in RTE food was almost as high as in raw foods, an indication of post-processing contamination likely due to inadequate hygiene practice. Other contributing factors include poor food safety governance systems, insufficient food hygiene education and presence of reservoirs and vectors in or near the food production or service areas. It is expected that GMP and HACCP will be introduced progressively, though gradual, in the food industry in the region for proactive intervention of microbial food safety along the food chain. Before that, education of food vendors and operators on good hygienic practices remains the most cost-effective way.

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Fig. 6. Prevalence of foodborne pathogens by country (Random Model Effects, $T^2 = 0.044$, $I^2 = 99.5\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, including the rate of prevalence (%) and 95% confidence interval (CI). Studies given higher weights are indicated by larger markers.