Review

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

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ABSTRACT

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

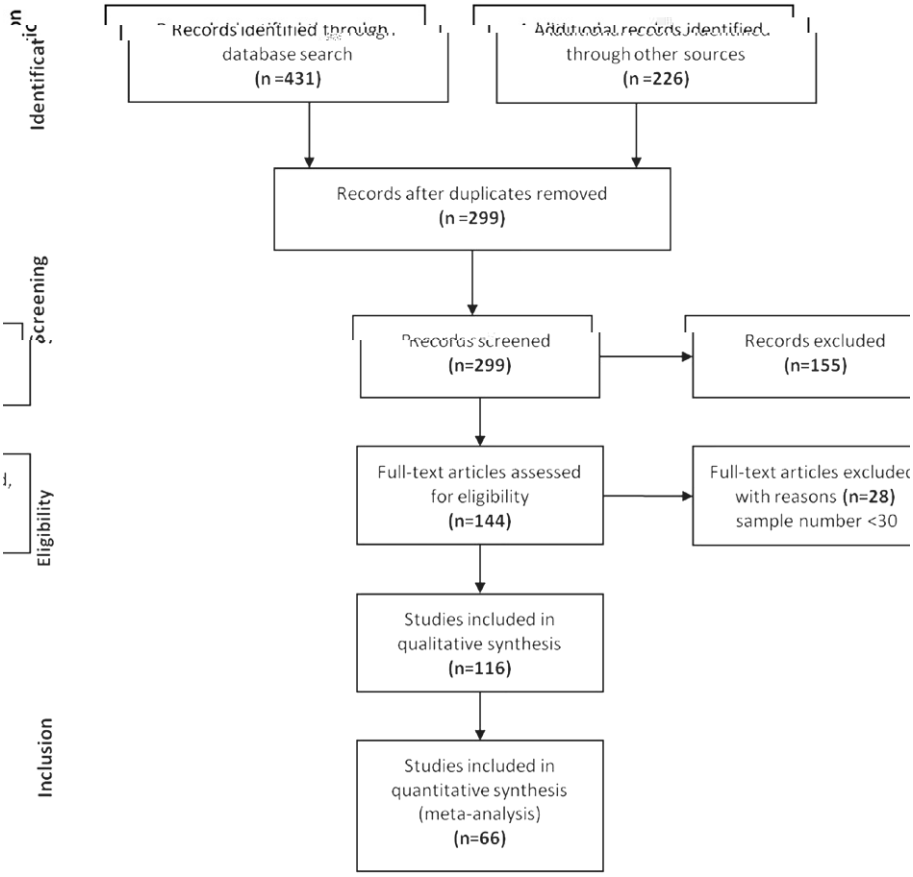

Fig. 1. Flow diagram of the literature search and selection of eligible studies.

water, bore-hole water), gruels, soups and some dipping pickles/sauces

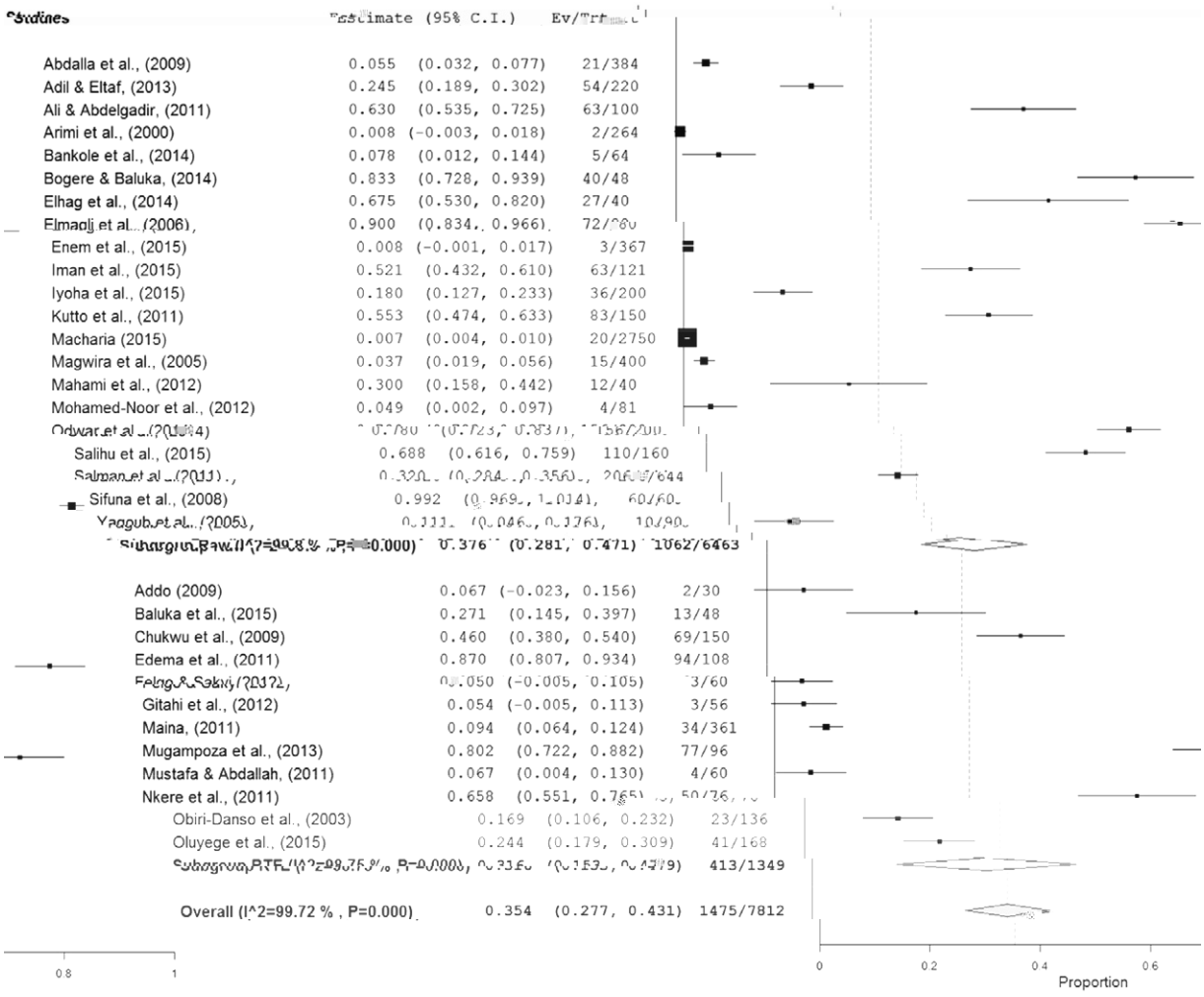

Fig. 2. Prevalence of *E. coli* (including ETEC, VTEC, STEC, EHEC) in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.050$, $I^2 = 99.72\%$, $p <$

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

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.

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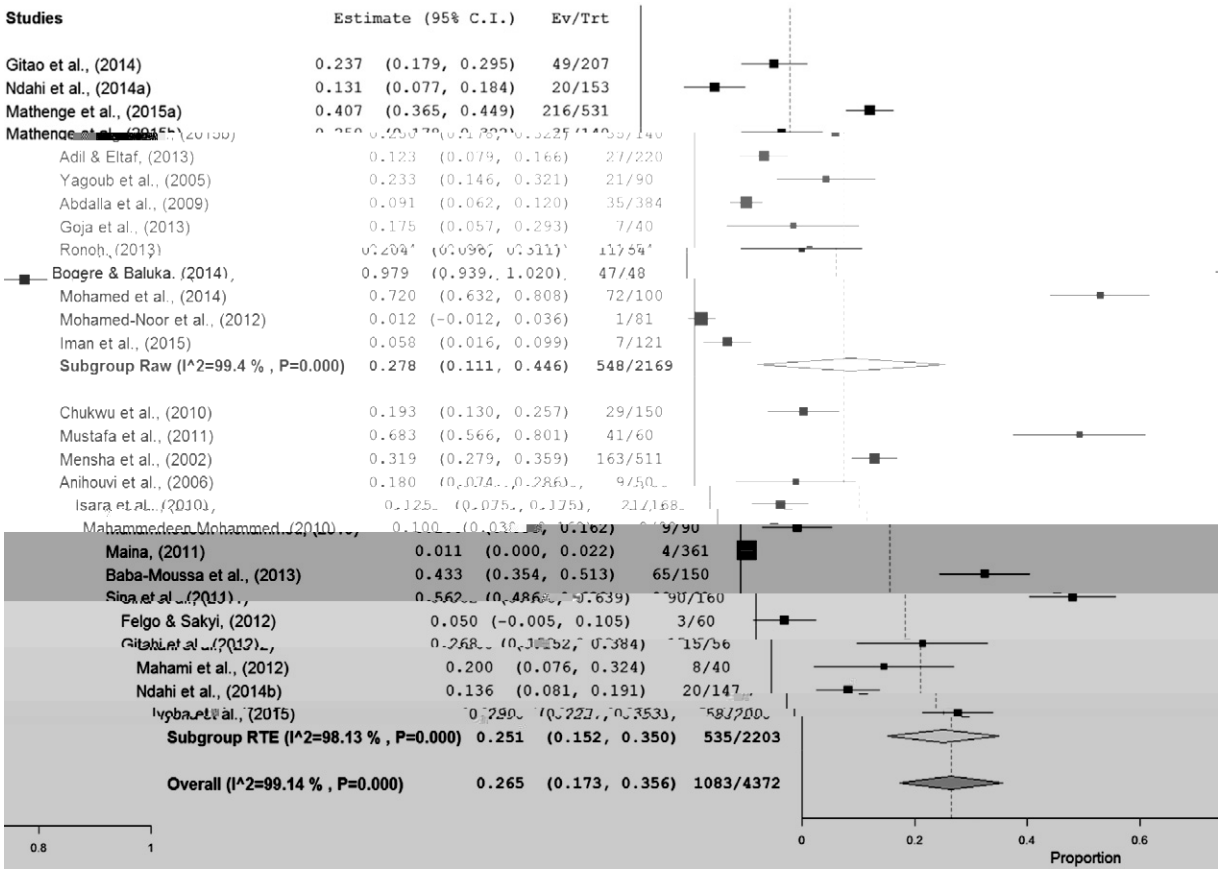


Fig. 4. Prevalence of *Staphylococcus aureus* in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.057$, $I^2 = 99.14\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, with the range of proportion in 95% confidence interval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

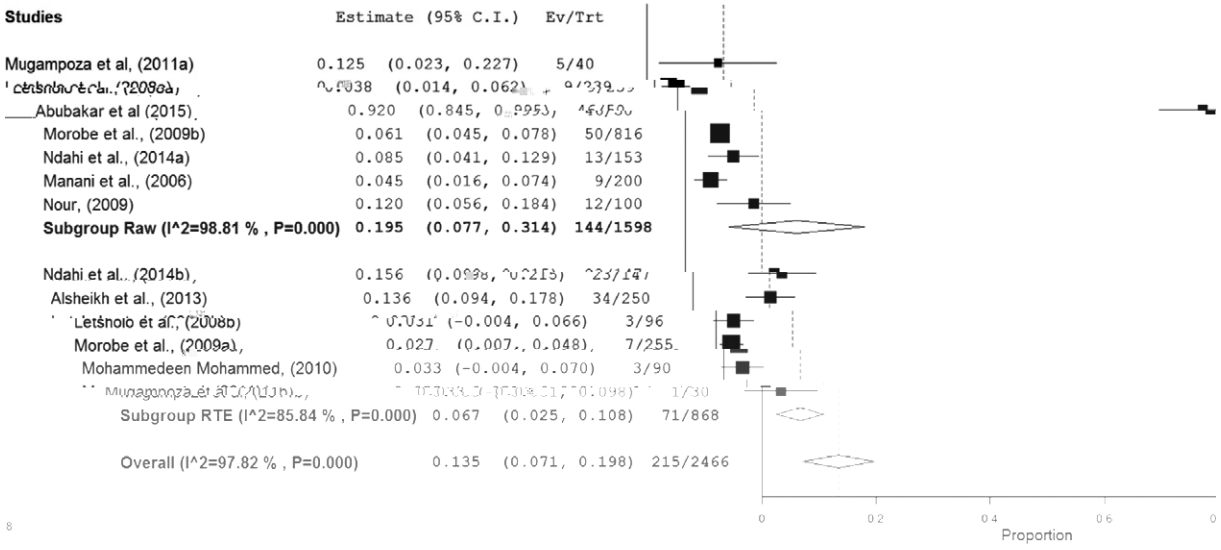
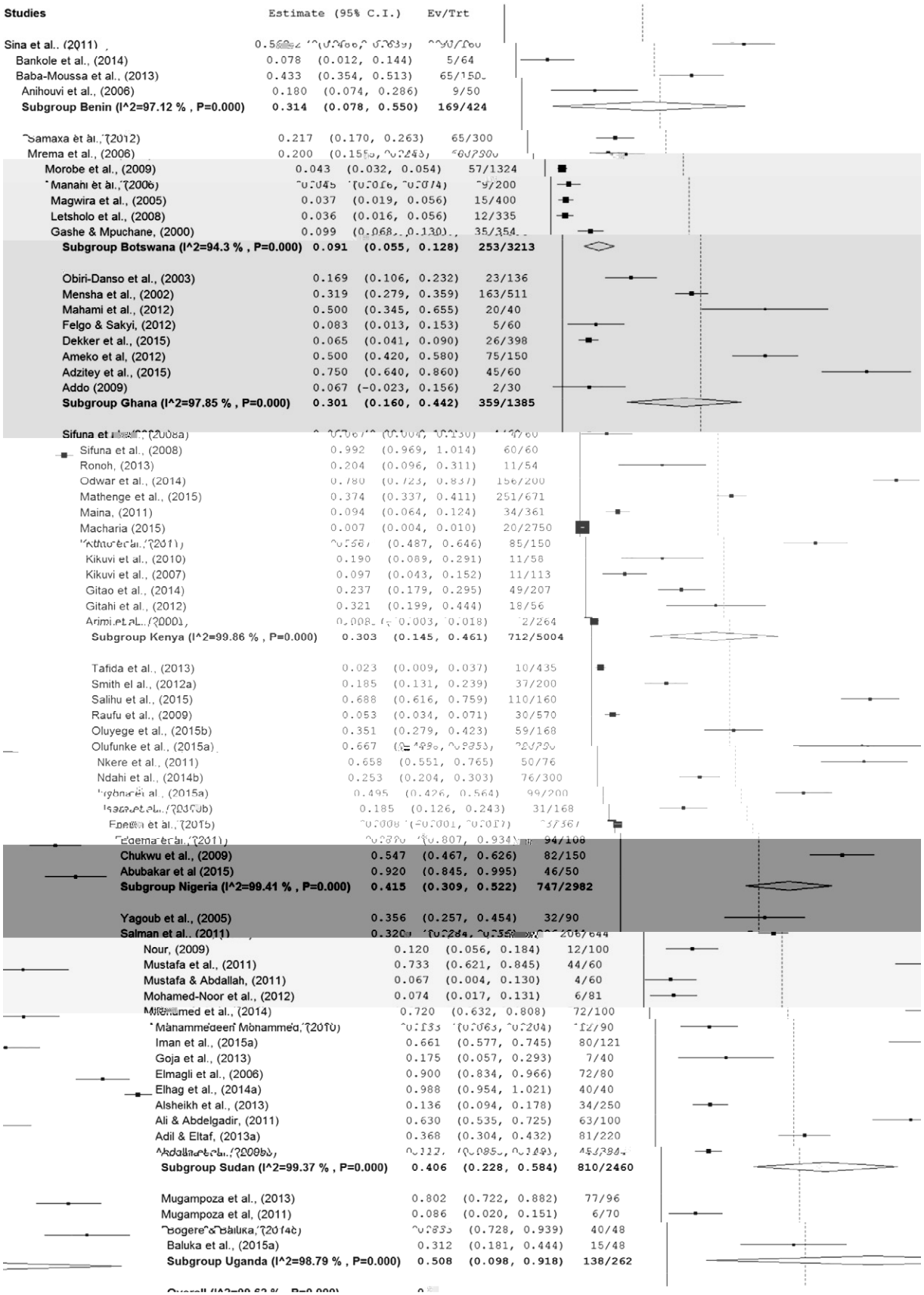


Fig. 5. Prevalence of *Listeria monocytogenes* in raw and ready-to-eat foods (Random Effects Model, $T^2 = 0.013$, $I^2 = 97.82\%$, $p < 0.001$). X-axis is the proportion of the organism reported in individual studies as listed along the Y-axis, with the range of proportion in 95% confidence interval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


Studies
Estimate (95% C.I.)
Ev/Trt
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
Morobe et al., (2009) 0.043 (0.032, 0.054) 57/1324
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., (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
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
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
Nkere et al., (2011) 0.658 (0.551, 0.765) 50/76
Ndahi et al., (2014b) 0.253 (0.204, 0.303) 76/300
Isaacs et al., (2015b) 0.185 (0.126, 0.243) 31/168
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
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
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
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
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

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