Received: 30 August 2019 | Revised: 1 December 2019 | Accepted: 7 January 2020

DOI: 10.1111/1541-4337.12533



COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY

Comprehensive REVIEWS in Food Science and Food Safety WILEY

# Microbiological safety of ready-to-eat foods in low- and middle-income countries: A comprehensive 10-year (2009 to 2018) review

**Oluwadamilola M. Makinde**[1] | **Kolawole I. Ayeni**[1] | **Michael Sulyok**[2] | **Rudolf Krska**[2,3] | **Rasheed A. Adeleke**[4] | **Chibundu N. Ezekiel**[1,2]

[1]Department of Microbiology, Babcock University, Ilishan Remo, Nigeria

[2]Department of Agrobiotechnology (IFA–Tulln), Institute of Bioanalytics and Agro-Metabolomics, University of Natural Resources and Life Sciences Vienna (BOKU), Tulln, Austria

[3]Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast, United Kingdom

[4]Department of Microbiology, North-West University, Potchefstroom, South Africa

**Correspondence**
Chibundu N. Ezekiel, Department of Microbiology, Babcock University, Ilishan Remo, 121103, Ogun State, Nigeria.
Email: chaugez@gmail.com

**Abstract**

Ready-to-eat foods (RTEs) are foods consumed without any further processing. They are widely consumed as choice meals especially by school-aged children and the fast-paced working class in most low- and middle-income countries (LMICs), where they contribute substantially to the dietary intake. Depending on the type of processing and packaging material, RTEs could be industrially or traditionally processed. Typically, RTE vendors are of low literacy level, as such, they lack knowledge about good hygiene and food handling practices. In addition, RTEs are often vended in outdoor environments such that they are exposed to several contaminants of microbial origin. Depending on the quantity and type of food contaminant, consumption of contaminated RTEs may result in foodborne diseases and several other adverse health effects in humans. This could constitute major hurdles to growth and development in LMICs. Therefore, this review focuses on providing comprehensive and recent occurrence and impact data on the frequently encountered contaminants of microbial origin published in LMICs within the last decade (2009 to 2018). We have also suggested viable food safety solutions for preventing and controlling the food contamination and promoting consumer health.

**KEYWORDS**

consumer protection, food safety, foodborne bacteria, mycotoxins, public health

## 1 | INTRODUCTION

Ready-to-eat foods (RTEs) are foods consumed without any further processing or preparations. They could be traditionally or industrially processed, packaged, or unpackaged and are usually considered to comprise, mainly, the publicly vended foods consumed immediately or later (Cerna-Cortes et al., 2015; FAO & WHO 2004; Von Holy & Makhoane, 2006). Similar to other regions, RTEs are widely consumed in low- and middle-income countries (LMICs) due to ease of production, availability, affordability, and palatability (Al Mamun, Rahman, & Turin, 2013a; Al Mamun, Rahman, & Turin, 2013b; Mensah, Yeboah-Manu, Owusu-Darko, & Ablordey, 2002). RTEs can be processed from single or mixed raw ingredients, such as cereals, fish, meat, nuts, and spices, into foods that may be liquid, semi-solid, or solid in consistency (Adebayo-Oyetoro et al., 2017; Ceyhun Sezgin & Sanher, 2016; Feglo & Sakyi, 2012). Based on the type of processing technique and packaging material, RTEs could range from traditionally processed foods such as *chaat* in India (Agrawal, Gupta, & Varma, 2008), *matoke* in Uganda (Bardi et al., 2014), and *warankasi* in Nigeria (Adeyeye, 2017) to industrially processed foods such as bread, biscuits, canned sardine, ice cream, and pizza. Depending on the type, RTEs can be

  

consumed by different groups of people ranging from children to adults. For instance, *kulikuli* is mostly consumed by children of school age as well as adults in Nigeria and Benin (Adjou, Yehouenou, Sossou, Soumanou, & De Souza, 2012; Ezekiel et al., 2013). In addition, RTEs are the preferred food by individuals who are often very busy and have less time to prepare meals while at work.

It is on record that many RTE vendors in LMICs often lack knowledge about good hygiene practices, which may predispose the foods to microbial contamination (Al Mamun et al., 2013a, 2013b; WHO, 2010). The situation is further complicated by the practice of vending RTEs in outdoor environments. Consequently, the foods are exposed to aerosols, insects, and rodents, which serve as sources of food contaminants (Fowoyo & Igbokwe, 2014; Mensah et al., 2002). The microbial contaminants of RTEs include bacteria (for example, species of *Bacillus*, coagulase negative Staphylococci, *Escherichia coli*, *Klebsiella pneumoniae*, *Listeria monocytogenes*, *Pseudomonas* spp., and *Staphylococcus aureus*; Annan-Prah et al., 2011; Fadahunsi & Makinde, 2018; Felgo & Sakyi, 2012; Gdoura-Ben Amor et al., 2018; Kharel, Palni, & Tamang, 2016; Tambekar, Jaiswal, Dhanorkar, Gulhane, & Dudhane, 2009), fungi (for example, diverse toxigenic species of *Aspergillus*, *Alternaria*, *Fusarium*, and *Penicillium*; Adjou et al., 2012; Oranusi & Nubi, 2016), parasites (for example, *Ascaris lumbricoides* and *Toxoplasma gondii*; Abd El-Razik, El Fadaly, Barakat, & Abu Elnaga, 2014; Manyi, Idu, & Ogbonna, 2014), and viruses (for example, hepatitis A virus; Yongsi, 2018). Additionally, the contaminating bacteria and fungi may further constitute increased public health risk by secreting toxic compounds such as cereulide (Ceuppens et al., 2011) and mycotoxins (IARC, 2015), respectively, at different stages during food production. Nonmicrobial-related RTE contaminants include heavy metals (for example, lead; Jalbani & Soylak, 2015) and pesticide residues (for example, tetradifon; Skretteberg et al., 2015) mostly found in plant-based RTEs, as well as polyaromatic hydrocarbons from car fumes and other industrial sources (Proietti, Frazzoli, & Mantovani, 2014). Depending on the type and concentration of contaminant, amount of food ingested by consumers, and health status of the consumer, acute or chronic foodborne diseases (FBD) may be result. On the other hand, continuous daily exposure to single or mixtures of these food contaminants via consumption of contaminated RTEs could produce a plethora of adverse health effects. Observable effects may range from mild to recurrent nausea, vomiting, and diarrhea (Ceuppens et al., 2011) to severe complications such as cancers, neural tube defects, and even human fatalities (Gibb et al., 2015; IARC, 2015; JECFA, 2017, 2018; Kamala et al., 2018; Wild & Gong, 2010). Thus, improperly prepared RTEs in LMICs, where regulations and monitoring for compliance are grossly inadequate, may constitute a huge risk to public health.

The World Health Organization (WHO) of the United Nations reported that LMICs, particularly those in the African and South-East Asian sub-regions, suffer significantly from the burden of FBD (Havelaar et al., 2015), sometimes resulting to huge economic losses. To put this into proper perspective, the World Bank estimates that the total productivity loss associated with FBD in LMICs is about US$44.4 billion per year, whereas the annual cost of treating these diseases costs several billion dollars (Jaffee, Henson, Unnevehr, Grace, & Cassou, 2019). Obviously, FBD constitute a major impediment to growth and development in the affected LMICs, because resources used in treating these preventable diseases could be redistributed into building other sectors of the economy (Alimi, 2016). In addition, FBD pose a threat to several of the Sustainable Development Goals of the United Nations in LMICs (FAO/WHO, 2018; Havelaar et al., 2015). Consequently, there is a need to intensify efforts to reduce microbial contamination of RTEs across LMICs. One way to achieve this is to harness recent data (2009 to 2018) on microbial contamination profiles of RTEs available in LMICs, with a view to providing information on the most likely encountered microbial contaminants and suggest viable solutions for preventing and controlling the menace. Food contaminants of microbial origin are prioritized in this review owing to their top-ranking on the list of foodborne hazards by the WHO (FAO/WHO, 2018).

Thus, this comprehensive decade (2009 to 2018) review focuses on (a) documenting the diversity of RTEs in LMICs; (b) identifying the potential contamination sources; (c) X-raying the adequacy of detection methods applied to food contaminants of microbial origin in the regions; (d) outlining the microbiologically related hazard groups and their health effects; and (e) proffering a cocktail of food safety solutions that could be applied in LMICs for the enhancement of the RTE chain and promotion of consumer/public health. For the purpose of this review, LMICs are considered to include low-income and lower middle-income countries based on the recent categorization by the World Bank for the 2020 fiscal year (World Bank, 2019).

## 2 | DIVERSITY OF RTEs IN LMICs

In different regions of LMICs, RTEs are adopted and accepted as part of the cuisine of the people, thus giving them an identity and heritage, which are often passed across generations (Kraig & Taylor, 2013). For example, *uttapam* processed from rice and *warankasi* obtained from raw milk are RTEs indigenous to the people of southern India and northern Nigeria, respectively (Iwuoha & Eke, 1996; Ray, Ghosh, Singh, & Mondal, 2016). Central to RTE processing are raw ingredients, which are mostly of plant (such as, grains, nuts, and spices) and animal origin (such as, fish, meat, and milk).

Typically, the choice of RTE ingredients is largely influenced by culture and belief, income, and socioeconomic status. For example, in some parts of the Middle East and North Africa, pork is considered as unacceptable; hence, it is replaced by other meat source (such as mutton or beef) in RTEs (Benkerroum, 2013). Despite the fact that RTEs are largely region specific, there is a high propensity to try out new types of foods introduced from other parts of the world, mostly due to human migration. RTEs such as *sharwama* (Middle East) and *samosa* (Middle East and Asia) have become globally acceptable and are widely consumed especially in several LMICs (Privitera & Nesci, 2015).

Interestingly, RTE recipes and processing techniques are often similar across regions despite their diversity, although the RTE local names largely differ. For example, the grilling or roasting technique commonly applied during meat processing into *nyama choma* in Kenya (Mwangi, den Hartog, Mwadime, van Staveren, & Foeken, 2002) is also applied to process meat into *suya* in Nigeria (Obadina, Oyewole, & Ajisegiri, 2013). Similarly, fava beans are fried with other ingredients to produce *falafel* in Egypt (El-Shenawy, El-Shenawy, Mañes, & Soriano, 2011) and *madlu'e* in Syria (Ceyhun Sezgin & Şanher, 2016). Table 1 shows the diversity of RTEs in some LMICs. Obviously, frying, roasting, and grilling are considered the prominent techniques employed in the RTE processing across LMICs.

## 3 | POTENTIAL SOURCES OF CONTAMINATION OF RTEs

In LMICs, RTEs are processed and sold under unhygienic conditions such that the risk of exposure to food contaminants is increased (Al Mamun et al., 2013a, 2013b; WHO, 2010). These conditions as well as other factors are discussed below.

### 3.1 | Quality of ingredients

The use of high-quality ingredients is critical to ensuring the safety of RTEs. However, in LMICs, it is common practice for vendors to purchase low-quality (often visibly bad) ingredients (such as cereals, legumes, spices, and vegetables) that are prone to heavy contamination by bacteria, fungi, and their toxins (Alimi, 2016) for RTE processing. Obvious reasons for the utilization of low-quality ingredients include poverty (less income to purchase high-quality ingredients); the need to generate more family income, which leads to purchase of large quantity of low-grade ingredients at low cost (often mixed with very small quantity of high quality ingredients) for RTE processing; and low awareness of the severity of FBD. To worsen the scenario, the low-quality ingredients are often not properly processed or are undercooked. Consequently, microbial spores or their toxins may be carried over into the finished products, thus constituting a health risk to the consumers (Alimi, 2016; Khairuzzaman, Chowdhury, Zaman, Al Mamun, & Bari, 2014).

### 3.2 | Contaminated food process chains

Central to RTE preparation is water, which is usually applied in large proportions during several processing steps such as dilution, fermentation, milling, steeping, and washing of RTE ingredients. Thus, it is crucial that water utilized for the processing of RTEs is free from microbiological contaminants. This is often not the case in many LMICs, especially in resource scarce rural settings, where potable water is not readily available (Ritchie & Roser, 2019; WHO, 2017). Consequently, water from questionable sources such as wells, streams, and rivers (sometimes stored for long periods in unsterilized open containers) is routinely applied during the processing of RTEs. Thus, the application of potentially contaminated water in RTE processing could predispose the foods to pathogenic bacteria such as *Campylobacter*, *E. coli*, *Salmonella*, *Pseudomonas*, and *Vibrio.* Consequently, consumers could be at risk of severe public health challenges (Rane, 2011).

Quality of food packaging materials is another critical factor to consider in evaluating the role of contaminated food process chains in RTE safety and consumer safety. In many LMICs, the choice of food packaging material depends on the type of RTE. Common packaging materials for locally processed RTEs include prewashed but unsterilized plastic bottles for packaging of liquid RTEs such as fermented beverages; polyethylene/nylon bags; or used paper (for example, newspapers). The utilization of these kinds of low-quality packaging materials may be direct source of pathogenic foodborne bacteria as well as fungal propagules; however, limited research data are available in this regard. Poor personal hygiene during food processing is an additional predisposing factor for RTE contamination during the process chain (Fellows & Hilmi, 2011). This is often facilitated by the low awareness level and poverty status of many of the local RTE processors in LMICs. Good personal hygiene is necessary during actual food preparation as well as during food packaging in order to limit RTE contamination.

### 3.3 | Unhygienic vending practices and conditions

Poor post-food production handling by vendors plays a key role in RTE contamination (Fellows & Hilmi, 2011). RTE vendors often lack good hygiene practices. A common scenario is vendors not washing their hands, the washing of hands with nonpotable (contaminated and unsterilized) water, or use of potable water but without detergents or disinfectants before RTEs are packaged. For instance, it is common vendor

**TABLE 1** Diversity of traditionally processed ready-to-eat foods in low- and middle-income countries

| Region | Country | Ready-to-eat food | Raw ingredients | Processing technique | References |
|---|---|---|---|---|---|
| Africa | Egypt | *Falafel* | Ground chickpeas and/or fava | Frying | El-Shenawy et al., 2011 |
| | Ethiopia | *Injera* and *Wot* | Tef bread, beef, lamb, chicken, goat, lentils, or chickpeas, with spicy Berbere | Cooking | Reda, Ketema, & Tsige, 2017 |
| | Ghana | *Banku kenkey* | Cassava/plantain and yams | Steaming/ boiling | Rheinländer et al., 2008 |
| | Kenya | *Nyama choma* with *Ugali* | Beef, veal, sheep, lamb, goat, and maize/cassava dough | Grilling and steaming | Mwangi et al., 2002 |
| | Morocco | *Merguez* | Lamb or beef, flour, and red pepper | Baking | Benkerroum, 2013 |
| | Nigeria | *Chin chin* | Wheat flour and eggs | Frying | Adebayo-Oyetoro et al., 2017 |
| | | *Suya* | Spiced meat and onions | Grilling | Obadina et al., 2013 |
| | | *Akara* | Beans | Frying | Omemu & Aderoju, 2008 |
| | | *Moi-moi* | Beans, pepper, and onions | Steamed/ boiled | Nkere, Ibe, & Iroegbu, 2011 |
| | Tanzania | *Ndizi Kaanga* | Bananas or plantains | Frying | Sanches-Pereira et al., 2017 |
| | Uganda | *Matoke* | Mashed plantain and groundnut sauce | Steaming/ boiling | Bardi et al., 2014 |
| Asia | India | *Chaat* | Flour, yoghurt, onions, sev, coriander, and spices | Frying | Agrawal et al., 2008 |
| | | *Pakoda* | Kodo millet, onions, green chillies, and spices | Frying | Deshpande, Mohapatra, Tripathi, & Sadvatha, 2015 |
| | | *Pani puri* | Unleavened Indian bread fried crisp, tamarind, chili, potato, onion, chickpeas, and various vegetables | Frying | Fellows & Hilmi, 2011 |
| | | *Samosa* | Flour, potato, onion, spices, oil, and salt | Frying | Kharel et al., 2016 |
| | Indonesia | *Nasi putih* | long-grain rice, chicken, pork, dog meat, goat, or beef, coconut milk | Cooked | Neufingerl et al., 2016 |
| | Pakistan | *Pahata roll* | Beef or chicken, bread, onions, tomato, and *raita* | Frying | Ceyhun Sezgin & Şanher, 2016 |
| | Philippines | *Siomai* | Squid, fish balls, chicken, and dipping sauces | Frying | Kraig & Taylor, 2013 |
| | | *Taho* | Bean curd, syrup, and tapioca balls | | Canini, Bala, Maraginot, & Mediana, 2013 |
| Caribbean | Haiti | *Mayi moulen* with *pikliz* | Rice, beans, cornmeal mush, kidney beans, coconut, and peppers with spicy pickled carrots and cabbage | Boiling, frying | Ceyhun Sezgin & Şanher, 2016 |
| Middle East | Palestine and Syria | *Madlu'e* | Sweet cheese curds, rich biscuit in Syrup, ground chickpeas, and/or fava beans | Frying | Ceyhun Sezgin & Şanher, 2016 |

practice to directly touch meat-based RTE (for example, *suya*) with unwashed hands during the postproduction slicing process. In addition, most vendors do not wear protective coverings (for example, nylon gloves) before the packaging of RTEs.

A major feature of RTE vending points in LMICs is their characteristic dirty surroundings. Vendors openly display the foods for sale in roadside make-shift sheds, which are sometimes situated close to dump sites or dirty stagnant roadside water. These serve as reservoirs to flies and other insects that are potential carriers of several bacterial pathogens (Lindh & Lehane, 2011). A study in Uganda revealed that 74.2% of vendors prepared food close to fly and insect infested trash receptacles (Muyanja, Nayiga, Brenda, &

Nasinyama, 2011). Furthermore, improperly washed vending utensils often contain leftover food particles suitable for proliferation of pathogenic microorganisms that could potentially cross-contaminate freshly prepared RTEs (Fellows & Hilmi, 2011; Muyanja et al., 2011). In many LMICs, the unhygienic vending condition is an easily controllable factor if regulations targeting RTEs and their vending become existent and are enforced.

## 4 | DETECTION OF CONTAMINANTS OF MICROBIOLOGICAL ORIGIN IN RTEs

Analytical techniques employed in the microbiological analysis of food typically include conventional (Mandal, Biswas, Choi, & Pal, 2011) and molecular methods (Law, Ab Mutalib, Chan, & Lee, 2015). A combination of these techniques, often referred to as "polyphasic approach," is usually applicable for high-throughput analysis of the food matrix (Randazzo, Scifo, Tomaselli, & Caggia, 2009). The application of conventional methods relies solely on the isolation of bacteria on general purpose or selective media (for example, nutrient agar, MacConkey agar, or eosin methylene blue) and of fungi on mycological media (such as, malt extract agar) (Samson, Houbraken, Thrane, Frisvad, & Anderson, 2019). Microbial isolation is typically followed by preliminary identification based on the assessment of morphological features including colony color, pigmentation, colony reverse color on selective media, microscopic characters, and reactions to a set of biochemical tests (for example, catalase, coagulase, and indole tests for bacteria) (Mandal et al., 2011). Majority of the studies on bacterial identification in RTEs in LMICs were solely based on conventional methods of microbe characterization (Table 2). The preferred application of conventional methods in microbial characterization in many LMICs is multifactorial including lack of molecular facilities, lack of expertise, inadequate research funding for human capacity, and infrastructural development. Although conventional methods are relatively cheaper compared to molecular methods, significant limitations such as laboriousness and low precision leading to species misidentification make the conventional method inappropriate for microbial typing (Law et al., 2015; Mandal et al., 2011; Zhao, Lin, Wang, & Oh, 2014).

In contrast, molecular methods offer a more sensitive and accurate mode of microbial identification (EFSA, 2013). These methods generally involve classifying pathogenic microorganisms based on genotypic traits as well as on genetic determinants known to increase their virulence and aid their adaptability to various food matrices (Hallin, Deplano, & Struelens, 2012; Mandal et al., 2011; Van Belkum et al., 2007). The ability of molecular techniques to accurately and rapidly detect pathogenic microorganisms known to cause FBD ensures source tracking and proper surveillance of RTEs (ECDC, 2013; Law et al., 2015). Consequently, high-throughput molecular methods such as next-generation sequencing and whole genome sequencing (WGS) add credence to inferences made from surveillance studies by highlighting phylogenetic similarities among microorganisms. WGS further provides information on the evolution of the microorganisms as well as their genetic determinants that could increase virulence and pathogenicity (Hazen et al., 2013; Leekitcharoenphon, Nielsen, Kaas, Lund, & Aarestrup, 2014). Aside the application of WGS in surveillance studies, it is an invaluable approach during cases of outbreaks because it gives a clearer picture of the possible source of outbreaks and provides sufficient data on ways to prevent the spread to other regions (Chin et al., 2011; Hendriksen et al., 2011). A typical example is the application of WGS in the 2010 cholera outbreak in Haiti, a LMIC. This technique revealed the *V. cholerae* strain(s) responsible for the outbreak may have been accidentally introduced from another geographical location (Chin et al., 2011; Hendriksen et al., 2011). Recently, molecular techniques including WGS have also been applied in other studies involving fermenters in traditional foods and pathogens in vegetable samples of LMIC origin (Adewumi, Oguntoyinbo, Keisam, Romi, & Jeyaram, 2013; Diaz et al., 2018; Ezekiel, Ayeni, et al., 2019; Igbinosa et al., 2018). These studies have mostly been conducted in collaboration with institutions in the North (Western world) where facilities and expertise are readily available; thus, technology and expertise transfer to LMICs are expected in the future.

In order to detect chemical contaminants of microbial origin in RTEs, several techniques including enzyme-linked immunosorbent assay (ELISA), high-performance liquid chromatography (HPLC), and liquid chromatography–tandem mass spectrometry (LC/MS–MS) can be applied. In most LMICs, the ELISA method represents the most viable technique for detection of frequently encountered chemical contaminants (for example, mycotoxins) in RTE foods. This is largely due to its low cost of analysis relative to high-end techniques such as the HPLC and LC–MS/MS. However, the ELISA technology has several limitations such as low sensitivity and inability to simultaneously detect multiple mycotoxins (Berthiller et al., 2013). In addition, ELISA kits are only readily available for the detection of single mycotoxins (for example, aflatoxin $B_1$, total aflatoxin, and ochratoxin A in foods). This constitutes a major hurdle to food safety especially in most LMICs, where there is frequent co-occurrence of multiple mycotoxins in dietary staples and RTE ingredients (Abia et al., 2017; Oyedele et al., 2017; Sombie et al., 2018; Warth et al., 2012). Thus, high-end chromatography–based techniques (for example, HPLC and the more

**TABLE 2** Bacterial contamination of ready-to-eat (RTE) foods in low- and middle-income countries (2009 to 2018)

| Region/ Country | RTE food | Potential source of contamination | Pathogen | Prevalence %(*n*/ *N*) | Analytical technique | References |
|---|---|---|---|---|---|---|
| Africa | | | | | | |
| Burkina Faso | Grilled chicken | Poor hygiene practices | *E. coli* | 27.45 (28/102)* | Conventional and Polymerase Chain Reaction (PCR) | Somda et al., 2018 |
| Cameroon | Cooked pork | Poor hygiene and sanitary practices | *E. coli*<br>*K. pneumoniae*<br>*S. aureus*,<br>*Salmonella*<br>*Proteus vulgaris*<br>*Shigella* spp. | 54.4 (6/11)*<br>72.7 (8/11)*<br>81.8 (9/11)*<br>45.4 (5/11)*<br>27 (3/11)*<br>9 (1/11)* | Conventional | Yannick, Rawlings, & Emmanuela, 2013 |
| Cote d'Ivoire | Cooked kebabs | Poor hygiene practices | *C. perfringens*<br>*C. difficile*<br>*C. sporogenes* | 13 (81/222)**<br>20.5 (27/222)**<br>21.2 (91/222)** | Conventional | Kouassi, Dadie, Nanga, Dje, & Loukou, 2011 |
| Democratic Republic of Congo | Bush meat<br>Smoked fish | Poor hygiene and handling practices | *Salmonella* sp.<br>*S. aureus*<br>*Salmonella* sp.<br>*S. aureus* | 56.25 (9/16)*<br>93.75 (15/16)*<br>50 (9/18)*<br>33.3 (6/18)* | Conventional | Makelele et al., 2015 |
| Egypt | *Shawarma* | Poor hygienic conditions | *Listeria* species<br>*L. monocytogenes*<br>*L. innocua* | 24 (138/576)*<br>57 (328/576)*<br>39 (225/576)* | Conventional | El-Shenawy et al., 2011 |
| Egypt | Sliced luncheon meat and chicken nuggets | Poor hygiene and food handling | MRSA | 37.5 (30/80)* | Conventional PCR-Restriction Fragment Length Polymorphism (RFLP) | El Bayomi et al., 2016 |
| Egypt | Burger sandwiches | | *Listeria* species | 60 (6/10)* | Conventional | Zaghloul et al., 2014 |
| Egypt | *Shawarma* with salads | | *C. jejuni*<br>*S. enterica*<br>*A. baumannii* | 31.8 (22/69)**<br>13.04 (9/69)**<br>8.69 (6/69)** | Conventional and MALDI-TOF | Elbehiry et al., 2017 |
| Ethiopia | *Ambasha* | Poor hygienic conditions | *E. coli*<br>*Proteus* spp.<br>*Klebsiella* spp.<br>*Citrobacter* spp. | 19 (4/21)***<br>28.5 (2/7)***<br>14.3 (1/7)***<br>33.3 (3/9)*** | Conventional | Eromo et al., 2016 |
| Ethiopia | *Sambusa*<br>*Bombolino*<br>*Macaroni* | Poor hygienic conditions | *S. aureus*<br>*E. coli*<br>*S. aureus*<br>*E. coli*<br>*S. aureus*<br>*E. coli* | 56.2 (9/16)**<br>37.5 (6/16)**<br>66.7 (9/12)**<br>50 (6/12)**<br>58.3 (7/12)**<br>75 (9/12)** | Conventional<br>Conventional<br>Conventional | Derbew et al., 2013, Derbew et al., 2013, Derbew, Sahle, & Endris, 2013 |

(Continues)

**TABLE 2** (Continued)

| Region/ Country | RTE food | Potential source of contamination | Pathogen | Prevalence %(*n*/ *N*) | Analytical technique | References |
|---|---|---|---|---|---|---|
| Ghana | *Ice-kenkey* and *Macaroni* | Poor food handling<br>Poor food handling | *Bacillus* sp.<br>CoNS<br>*Klebsiella* sp. *Enterobacter* sp.<br>*E. coli*<br>*S. aureus*<br>*Aeromonas* sp.<br>*Bacillus* sp.<br>CoNS<br>*Klebsiella* sp. *Enterobacter* sp.<br>*S. aureus*<br>*Aeromonas* sp. | 5.9 (8/135)**<br>7.4 (10/135)**<br>0.7 (1/135)**<br>0.7 (1/135)**<br>0.7 (1/135)**<br>1.5 (2/135)**<br>3.0 (4/135)**<br>3.0 (4/135)**<br>4.4 (6/135)**<br>5.9 (8/135)**<br>0.7 (1/135)**<br>0.7 (1/135)**<br>4.4 (6/135)** | Conventional<br>Conventional | Felgo & Sakyi, 2012<br>Felgo & Sakyi, 2012 |
| Ghana | Fried rice | Poor hygiene practices | *E. cloacae*, *E. coli*, *K. pneumoniae*, and *S. aureus* | NA (NA) | Conventional | Yeboah-Manu, Kpeli, Akyeh, & Bimi, 2010 |
| Madagascar | RTE pork | Poor hygiene practices | *Salmonella* spp. | 5.0 (9/178)* | Conventional and serology | Cardinale et al., 2015 |
| Nigeria | *Wara*, *Kununzaki*, Smoked fish, and Meat-pie | Poor hygienic conditions | *P. aeruginosa*, *P. putida*, and *P. mendocina* | NA (NA) | Conventional | Fadahunsi & Makinde, 2018 |
| Nigeria | *Suya* | Poor hygienic conditions | *E. coli*, *Staphylococcus* spp., *Pseudomonas* spp., *C. septicum*, *Micrococcus* spp., and *B. alvei* | NA (NA) | Conventional | Adio, Ovuoraini, & Olubunmi, 2014 |
| Nigeria | Locally processed fruit juice | Poor quality water | *Enterococcus* spp., *E. coli*, *Bacillus* sp., and *Staphylococcus* sp. | NA (NA) | Conventional | Agwa, Ossai-Chidi, & Ezeani, 2014 |
| Nigeria | Boiled rice and beans<br>Bread | Poor food handling | *E. coli*<br>*E. coli* | 100 (5/5)*<br>40 (2/5)* | Conventional | Bukar et al., 2009<br>Bukar et al., 2009 |
| | *Zobo* drink | | *E. coli*<br>*S. typhi* | 20 (1/5)*<br>20 (1/5)* | | Bukar et al., 2009,<br>Bukar et al., 2009 |
| Nigeria | *Akara* and fried potato | Poor food handling practices | *S. aureus* and *E. coli* | NA (NA) | Conventional | Madueke, Awe, & Jonah, 2014 |
| | Fried yam | Poor food handling practices | *K. pneumoniae* | NA (NA) | Conventional | Madueke et al., 2014 |
| Nigeria | Cooked meat | Poor hygiene and sanitation practice | *Salmonella* spp. | 18 (9/50)* | Conventional and PCR | Smith et al., 2012 |

(Continues)

**TABLE 2** (Continued)

| Region/ Country | RTE food | Potential source of contamination | Pathogen | Prevalence %(*n*/ *N*) | Analytical technique | References |
|---|---|---|---|---|---|---|
| Nigeria | Meat pie | Poor food handling practices | *Bacillus* spp.<br>*S. aureus*<br>*Klebsiella* spp.<br>*Proteus* spp.<br>*E. coli*<br>*Shigella* spp.<br>*Citrobacter* | 85.0 (153/180)*<br>38.9 (70/180)*<br>18.9 (34/180)*<br>17.8 (32/180)*<br>10.0 (18/180)*<br>5.0 (9/180)*<br>5.0 (9/180)* | Conventional | Obande, Umeh, Azua, Chuku, & Adikwu, 2018 |
| Nigeria | Egg roll | | *B. atrophaeus* and *B. amyloliquefaciens* | NA (NA) | 16S rDNA sequencing | Aruwa & Ogunlade, 2016 |
| | Meat pie | | *B. thuringiensis* and *B. subtilis* | NA (NA) | 16S rDNA sequencing | Aruwa & Ogunlade, 2016 |
| | *Buns* | | *B. licheniformis* | NA (NA) | 16S rDNA sequencing | Aruwa & Ogunlade, 2016 |
| Kenya | Street vended meat | Poor hygiene practices | *S. aureus* | 66.7 (6/9)* | Conventional and PCR | Gitahi, Wangoh, & Njage, 2012 |
| Rwanda | Boiled beef, grilled chicken, grilled goat meat, grilled rabbit, and fried pork | Poor hygiene practices | *Salmonella* | 11.7 (35/300)* | Conventional | Niyonzima et al., 2017 |
| Sudan | *Um-Jinger* | Poor hygiene practices | *Bacillus* spp.<br>*S. aureus*<br>*E. coli*<br>*Salmonella* spp.<br>*Proteus* spp. | 70.0 (42/60)*<br>68.3 (41/60)*<br>6.6 (4/60)*<br>5 (3/60)*<br>8.3 (5/60)* | Conventional | Abdallah & Mustafa, 2010 |
| Sudan | *Shawarma* | Poor food handling | *E. coli*<br>*S. aureus*<br>*Salmonella* | NA (NA) | Conventional | Elfaki & Elhakim, 2011 |
| Tanzania | Raw juice | Poor hygiene practices | *E. coli* | 63.3 (19/30)* | Conventional | Nonga et al., 2015 |
| Tunisia | Cooked poultry meat | | *B. cereus* | 32.7 (18/55)* | Conventional, PCR, and Pulsed-Field Gel Electrophoresis (PFGE) | Gdoura-Ben Amor et al., 2018 |
| | pastries | | *B. cereus* | 46.2 (37/80)* | Conventional, PCR, and PFGE | Gdoura-Ben Amor et al., 2018 |
| Asia | | | | | | |
| Bangladesh | Sweets and dairy products | Poor hygiene and sanitation practice | *V. cholerae* | NA (NA) | Conventional | Mrityunjoy et al., 2013 |

(Continues)

**TABLE 2** (Continued)

| Region/ Country | RTE food | Potential source of contamination | Pathogen | Prevalence %(*n*/ *N*) | Analytical technique | References |
|---|---|---|---|---|---|---|
| Bangladesh | *Chotpoti* | Poor hygiene | *Acinetobacter*<br>*E. coli*<br>*Klebsiella* spp.<br>*Proteus* spp. | 66 (71/108)*<br>3 (3/108)*<br>54 (58/108)*<br>0.9 (1/108)* | Conventional | Hassan et al., 2016 |
| Bangladesh | *Chatpati* | Poor hygiene practices | *Cronobacter sakazakii*<br>*Listeria* spp.<br>*Salmonella* spp.<br>*Yersinia* spp. | 100 (3/3)*<br>33.3 (1/3)*<br>66.7 (2/3)*<br>100 (3/3)* | Conventional | Tabashsum et al., 2013 |
| Bangladesh | *Jhalmuri* | Poor food handling practices | Coliform bacteria | 59.1 (13/22)* | Conventional | Al Mamun et al., 2013a |
| | *Chotpoti* | Poor food handling practices | Coliform bacteria | 29.4 (5/17)* | Conventional | Al Mamun et al., 2013a |
| Indonesia | RTE noodle with chicken | Poor hygiene | Coliform bacteria and *S. aureus* | NA (NA) | Conventional | Adolf & Azis, 2012 |
| India | Fruit juice | Poor water quality, unhygienic conditions | *E. coli*<br>*Pseudomonas* spp.<br>*Salmonella* spp.<br>*Klebsiella* spp. | 40 (31/77)**<br>25 (19/77)**<br>16 (12/77)**<br>3 (2/77)** | Conventional | Tambekar et al., 2009 |
| India | RTE foods | Poor hygiene practices | *E. coli* | 74 (37/50)* | Conventional, RFLP | Biswas et al., 2010 |
| India | *Chowmein* | Poor hygiene practices | *B. cereus*, *E. coli*, *Salmonella*, and *Shigella* | NA (NA) | Conventional | Chauhan, Uniyal, & Rawat, 2015 |
| India | Ice cream | Poor hygiene and sanitary practices | *Y. intermedia* | 5 (1/20)* | Conventional and PCR | Divya & Varadaraj, 2011 |
| | *Pani puri* | | *Y. intermedia* | 4 (2/20)* | Conventional and PCR | Divya & Varadaraj, 2011 |
| | Bread sandwiches | | *Y. enterolitica* | 5 (1/20)* | Conventional and PCR | Divya & Varadaraj, 2011 |
| India | *Chutney* | | *B. cereus* (Biotype 6)<br>*B. cereus* (Biotype 5) | 38.46 (5/13)**<br>23.07 (3/13)** | Conventional | Hafeez, Iqbal, & Ahmad, 2012 |
| | Mutton *tikka* | | *B. cereus* (Biotype 3)<br>*B. cereus* (Biotype 4) | 29.63 (8/27)**<br>25.93 (7/27)** | Conventional | Hafeez et al., 2012 |
| India | Bread *chop* and *Samosa* | Poor hygiene practices | *Bacillus* and *Staphylococcus* | NA (NA) | Conventional and Serology | Kharel et al., 2016 |

(Continues)

**TABLE 2** (Continued)

| Region/ Country | RTE food | Potential source of contamination | Pathogen | Prevalence %(*n*/ *N*) | Analytical technique | References |
|---|---|---|---|---|---|---|
| India | Dairy products | Poor food handling practices | MRSA | NA (NA) | Conventional, MALDI–TOF, and PCR | Manukumar & Umesha, 2017 |
| Nepal | Fried rice | Poor hygiene practices | *B. cereus*<br>*S. aureus*<br>*S. typhi* | 23.8 (5/21)**<br>19 (4/21)**<br>9.5 (2/21)** | Conventional | Ankita et al., 2012 |
| Nepal | Chicken *momo*, *samosa* | Poor hygiene and poor food handling practices | *Staphylococcus* and *Salmonella* | NA (NA) | Conventional | Bohara, 2018 |
| Nepal | *Puri* | Poor hygiene and poor food handling practices | *S. aureus*<br>*E. coli*<br>*B. cereus*<br>*Citrobacter* spp. | 55.5 (20/36)**<br>5.5 (2/36)**<br>27.7 (10/36)**<br>11 (4/36)** | Conventional | Khadka, Adhikari, Rai, Ghimire, & Parajuli, 2018 |
| Pakistan | Pasteurized juice | Poor hygiene practices | *E. coli*, *Salmonella*, *Staphylococcus*, and *Pseudomonas* | NA (NA) | Conventional | Batool et al., 2013 |
| India | *Panipuri* | Poor hygiene practices | *E. coli*<br>*Klebsiella* spp. | 6.25 (5/80)*<br>2.5 (2/80)* | Conventional | Kiranmai, Siva Kamesh, Divija, & Sara, 2016 |
| Philippines | Hot grilled pork, hot grilled chicken | Poor hygiene practices | *E. coli*, *S. aureus*, *B. cereus*, and *Salmonella* | NA (NA) | PCR-based detection kits | Manguiat & Fang, 2013 |
| Vietnam | Grilled pork meat | Poor hygiene practices | *S. aureus* | 21.8 (7/32)* | Conventional and RFLP | Huong et al., 2009 |
| | Ice cream | | *S. aureus* | 25 (3/12)* | Conventional and RFLP | Huong et al., 2009 |
| | Fermented meat | | *S. aureus* | 13.8 (4/29)* | Conventional and RFLP | Huong et al., 2009 |

*Note*. Abbreviations: *n*, number of pathogen; *N*, number of samples/isolates/particular species; NA, not available; *A. baumannii*, *Acinetobacter baumannii*; *B. cereus*, *Bacillus cereus*; *B. alvei*, *Bacillus alvei*; *C. difficile*, *Clostridium difficile*; *C. perfringens*, *Clostridium perfringens*; *C. sporongenes*, *Clostridium sporongenes*; *C. septicum*, *Clostridium septicum:* CoNS, coagulase negative staphylococci; *E. coli*, *Escherichia coli*; *E. cloacae*, *Enterobacter cloacae*; *K. pneumonia*, *Klebsiella pneumonia*; *MRSA*, Methicillin-resistant *S. aureus*; *P. aeruginosa*, *Pseudomonas aeruginosa*; *P. putida*, *Pseudomonas putida*; *P. mendocina*, *Pseudomonas mendocina*; *S. aureus*, *Staphylococcus aureus*; *Y. intermedia*, *Yersinia intermedia*; *Y. enterolitica*, *Yersinia enterolitica*.

*Number of samples

**Number of isolates

***Number of a particular species

sensitive LC/MS–MS) are applied to give a more precise result and accurately quantify the concentration levels of multiple mycotoxins in several foods (Berthiller et al., 2018; Malachova, Sulyok, Beltran, Berthiller, & Krska, 2014). The application of these high-end techniques represents the gold standards for detection of multiple mycotoxins in food. However, these techniques are expensive and there is lack of skilled expertise in most LMICs, which makes routine application impracticable.

## 5 | PATHOGENIC BACTERIA IN RTEs FROM LMICs

The ability of pathogenic bacteria to proliferate in RTEs depends on several intrinsic (for example, nutrient composition) and extrinsic (for example, environmental temperature) factors (Smith & Fratamico, 2005). Upon consumption of contaminated foods, pathogenic bacteria can cause a wide range of adverse health effects including gastrointestinal-related diseases, thus constituting a huge health risk to consumers. The development of adverse health effects is, however, dependent on several factors including, but not limited to, number of pathogenic bacteria present in the food, age, and level of immunity of the consumer. In this section, we have clustered the diverse bacteria reported in RTEs across LMICs into two broad groups: Gram-negative and Gram-positive.

### 5.1 | Gram-negative bacteria

This group of bacterial species can be found in a wide range of habitats including the gastrointestinal tract of humans and animals. They contribute significantly to the FBD burden in LMICs (Kirk et al., 2015a, 2015b). Of major concern to food safety is the ability of some members, for example, *Vibrio cholerae* and *Salmonella* spp., to transfer and/or acquire virulent genes thereby leading to the proliferation of highly virulent strains (Alcaine et al., 2005; Seitz & Blokesch, 2013). Consequently, the presence of these strains in food could render it unsafe for human consumption and obviously threaten the health of the consumers. Diverse Gram-negative bacteria have been reported to contaminate RTEs across LMICs (Table 2). Among these, *E. coli*, *Klebsiella* species, *Salmonella*, and *Pseudomonas* were commonly reported. Abdallah and Mustafa (2010) and Bukar, Uba, and Oyeyi (2009) detected *Salmonella* in street-vended juice in Sudan (North Africa) and in *zobo* from Nigeria (West Africa), respectively. In addition, Biswas, Parvez, Shafiquzzaman, Nahar, and Rahman (2010) and Yannick, Rawlings, & Emmanuela (2013) reported the presence of *E. coli* in RTE meat from Bangladesh (Asia) and Cameroon (Central Africa), respectively, whereas diarrheagenic *E. coli* strains were recovered from grilled chicken in Burkina Faso (West Africa) (Somda et al., 2018). Similarly, *Pseudomonas* was detected in street-vended juice in Pakistan, (Batool, Tahir, Rauf, & Kalsoom, 2013), whereas in Bangladesh (Asia) and Ethiopia, *Klebsiella* was found to contaminate *chotpoti* and *ambasha*, respectively (Eromo, Tassew, Daka, & Kibru, 2016; Hassan et al., 2016).

### 5.2 | Gram-positive bacteria

Notable foodborne pathogens within this group (such as, *Bacillus*, *Listeria*, and *Staphylococcus*) are able to tolerate harsh food storage and processing conditions such as low temperature, low moisture content, and high acidity and salinity (De Noordhout et al., 2014; Kadariya, Smith, & Thapaliya, 2014; Stecchini, Del Torre, & Polese, 2013; Swarminathan & Smidt, 2007). These capabilities make them a major concern to food safety. Some species (such as, *Listeria monocytogenes*) are opportunistic in nature and can cause high mortality rates among infants, older adults, and immunocompromised individuals (Guillet et al., 2010; Nyenje, Green, & Ndip, 2012). There have been several reports on contamination of RTEs by Gram-positive bacteria especially *Bacillus* species, *Listeria* species, and *Staphylococcus aureus* across LMICs (Table 2). *Staphylococcus aureus* was detected in grilled pork meat, ice cream, and fermented meat in Vietnam (Asia) (Huong et al., 2009), whereas *Bacillus* species were recovered from *Um-Jinger* in Sudan (North Africa) (Abdallah & Mustafa, 2010). In Nepal (Asia) and India, *S. aureus* were also recovered from fried rice and *samosa*, respectively (Ankita, Prasad, & Umesh, 2012; Kharel et al., 2016). In addition, Tabashsum et al. (2013) and Zaghloul et al. (2014) reported *Listeria* in *pitha* and burger sandwiches from Bangladesh and Egypt (North Africa), respectively. In another study in the Democratic Republic of Congo, *S. aureus* was recovered from bush meat (Makelele et al., 2015). Diverse species of *Bacillus*, including *B. cereus*, were also detected in several RTEs including *meat pie*, *buns*, and jollof rice from Nigeria (Aruwa & Ogunlade, 2016). Similarly, in Tunisia, *B. cereus* contaminated cooked poultry meat and pastry products (Gdoura-Ben Amor et al., 2018).

## 6 | BACTERIAL TOXINS IN RTEs FROM LMICs

Beyond the mere presence of pathogenic bacteria in RTEs, bacteria sometimes secrete potent toxins that could pose additional health risks to the food consumers. Of particular importance are cereulide, botulinum toxin, and staphylococcal exotoxins discussed hereafter. Generally, there are sparse data on the detection of bacterial toxins in RTEs from LMICs in the decade under study. Obvious reasons include (a) lack of trained personnel and equipment for detection of bacterial

toxins in RTEs and (b) possible biased interest of food microbiologists toward viable bacteria than on their toxins.

### 6.1 | Botulinum toxin

The botulinum toxin is a potent neurotoxin produced by toxigenic strains of *Clostridium botulinum* (Popoff, 2013). Ingestion of botulinum toxin through consumption of RTEs may result in botulism, a neuroparalytic disease that could be fatal in humans (Johnson & Montecucco, 2018). The presence of the botulinum toxin gene (BoNt/A) was reported in 4% of toxigenic strains of *Clostridium* species isolated from RTEs in Nigeria (Chukwu et al., 2016). However, no study has reported the presence of the toxin in RTEs in LMICs within the period under review.

### 6.2 | Cereulide

Cereulide is an emetic exotoxin from certain *Bacillus cereus* strains. It is highly stable at extreme temperature and pH, with report on stability at 121 °C for 2 hr and over the pH range of 2 to 11, which makes it very difficult to inactivate during food processing (Ceuppens et al., 2011; Rajkovic, Uyttendaele, & Debevere, 2005). Additionally, cereulide is particularly toxic to infants, sometimes causing acute toxicity (Shiota et al., 2010). Cereulide is able to contaminate a range of RTEs such as improperly cooked and stored rice, pasta, eggs, milk, and meat (Ceuppens, Boon, & Uyttendaele, 2013). To worsen the scenario, this toxin sometimes co-occurs with other potent fungal toxins in RTEs. Such co-occurrence may lead to additive and/or synergistic effects that could possibly compound the health risk to consumers upon ingestion (Beisl et al., 2019). Recently, one LC–MS/MS-based study reported the presence of cereulide (mean: 37 $\mu$g/kg) in all 50 RTE maize *fufu* from Cameroon, with 20% and 100% co-occurrence of aflatoxins and deoxynivalenol, respectively, in addition to other mycotoxins (Abia et al., 2017).

### 6.3 | Staphylococcal exotoxins

The staphylococcal exotoxin is a heat stable super-antigenic toxin (SAgs) produced predominantly by coagulase positive and a few coagulase negative Staphylococci (Even, Leroy, & Charlier, 2010; Zell et al., 2008). Staphylococcal exotoxins are responsible for food poisoning and toxic shock syndrome often characterized by vomiting, especially in immunocompromised individuals (Argudin, Mendoza, & Rodicio, 2010; Hennekinne, De Buyser, & Dragacci, 2012; Hu et al., 2007; Pinchuk, Beswick, & Reyes, 2010; Schelin et al., 2011). Staphylococcal food poisoning can be traced to poor handling of foods by handlers carrying enterotoxigenic *S. aureus* in their hands or noses, which may contaminate food products during packaging (Argudin et al., 2010). RTEs commonly implicated in *S. aureus* contamination include cakes, dairy products, flour-based products, meat pie fillings, salads, and sandwiches (Argudin et al., 2010). El Bayomi et al. (2016) reported the incidence of *S. aureus* in RTE chicken products in Egypt, but did not report the production of staphylococcal exotoxin by the bacterial isolates or its presence in the RTE. However, Huong et al. (2009) reported that 40% ($n = 45$) of *S. aureus* recovered from RTEs in Vietnam were enterotoxigenic.

## 7 | FUNGAL CONTAMINATION OF RTEs FROM LMICs

Fungal contamination of RTEs is commonplace in LMICs due to vendor practice of displaying the foods openly in markets, such that they are exposed to fungal spores. Diverse fungal genera contaminate food materials, but the frequently occurring ones in RTEs include *Aspergillus*, *Fusarium*, *Mucor*, *Penicillium*, and *Rhizopus*. *Aspergillus* and *Fusarium* were reported to contaminate retailed *kulikuli* (peanut cake) and salads from Benin Republic, Togo, and Nigeria (Adjou et al., 2012; Adjrah et al., 2013; Ezekiel et al., 2011). Similarly, *Aspergillus* and *Penicillium* were reported in street-vended doughnut, egg roll, and meat pie from Nigeria (Oranusi & Braide, 2012). In India, *Mucor* and *Rhizopus* contaminated street-vended rice-based *bhelpuri* (Das, Nagananda, Bhattacharya, & Bhardwaj, 2010). Although diverse fungal propagules can be recovered in RTEs, these viable fungi pose far less public health menace compared to the occurrence of their toxic secondary metabolites (mycotoxins) liberated into the foods.

### 7.1 | Mycotoxins in RTE ingredients

Several RTEs in LMICs are mostly cereal and nut based. These ingredients are known to be prone to toxigenic fungal contamination. Mycotoxigenic fungal species within the *Aspergillus*, *Fusarium*, *Penicillium*, and *Alternaria* genera can proliferate and produce toxic metabolites in the crops under favorable climatic conditions and poor pre- and postharvest practices, similar to those prevalent in tropical and subtropical regions where many LMICs are situated (Bankole, Schollenburger, & Drochner, 2006; Bhat & Vasanthi, 2003; IARC, 2015). The major mycotoxins of food safety importance include aflatoxins (AFs), fumonisins (FUM), ochratoxin A (OTA), citrinin, deoxynivalenol (DON), and zearalenone (ZEN).

Recent data on mycotoxin occurrence in raw grains from Africa and Asia allude to the severity of the mycotoxin menace in these regions (Ayalew, Hoffmann, Lindahl, & Ezekiel, 2016; Ezekiel et al., 2018; Misihairabgwi, Ezekiel, Sulyok, Shephard, & Krska, 2019; Pereira, Fernandes, &

Cunha, 2014). Of particular importance are AFs, FUM, and DON, which appear to occur more frequently at high levels in raw grains. Typical examples are the very high levels of AFs in groundnuts from Nigeria (max: 2,076 $\mu$g/kg) and Sierra Leone (max: 5,729 $\mu$g/kg) (Oyedele et al., 2017; Sombie et al., 2018), and in maize from Tanzania (max: 1,081 $\mu$g/kg) and Somalia (max: 1,407 $\mu$g/kg) (Kamala et al., 2015; Probst, Bandyopadhyay, & Cotty, 2014). To worsen the scenario, several mycotoxins often co-occur in RTE ingredients from LMICs. For example, AFs, FUM, and DON have been reported to simultaneously occur in maize from Burkina Faso, Cameroon, Mozambique, and Nigeria (Abia et al., 2013; Adetunji et al., 2014; Warth et al., 2012), whereas AFs and OTA co-occurred in rice from Pakistan (Majeed, Iqbal, Asi, & Iqbal, 2013).

### 7.2 | Mycotoxins in RTEs

Processing techniques (such as grain washing, fermentation, dilution, and heat treatment) routinely applied during RTE production may influence mycotoxin levels in the finished product (Ezekiel, Ayeni, et al., 2019; Ezekiel, Sulyok, et al., 2019; Karlovsky et al., 2016; Okeke et al., 2015, 2018). Nonetheless, mycotoxins in ingredients are commonly carried over to the final product albeit in varying concentrations depending on the toxin levels in the starting raw material (Ezekiel et al., 2015; Ezekiel, Ayeni, et al., 2019; Matumba et al., 2014; Okeke et al., 2015). Mycotoxin carry-over is typical, particularly in resource scarce rural settings, where local food processors commonly apply low-quality grains in the production of RTEs because high-quality grains are often sold for household income (Ayalew et al., 2016; Misihairabgwi et al., 2019). Consequently, human consumption of mycotoxin contaminated RTEs could constitute health hazards and some of which could include, but are not limited to, cancers, gastrointestinal barrier alterations, immunosuppression, growth faltering, and nephrotoxicity (IARC, 2015).

Details of mycotoxin contamination levels in RTEs across LMICs in the decade under review are highlighted in Table 3. Aflatoxins appear to be the most frequently studied mycotoxins in RTEs in LMICs, possibly due to their categorization as the most toxic and carcinogenic of all mycotoxins (IARC, 1993). Obviously, massive contamination levels in this group of foods widely consumed by all age groups have been reported in literature. Concentration ranges of the most potent carcinogenic mycotoxin, aflatoxins, have reached 2,820 and 3,328 $\mu$g/kg in peanut cake (*kulikuli*) and roasted peanuts from Nigeria and Sierra Leone, respectively (Ezekiel, Sulyok, Warth, Odebode, & Krska, 2012; Sombie et al., 2018). In addition, other mycotoxins have been reported to co-occur with aflatoxins in RTEs from several countries. These include OTA in peanut cake from Benin (Adjou et al., 2012; Ediage, Mavungu, Monbaliu, Van Peteghem, & De Saeger, 2011); beauvericin and OTA in peanut cake from Nigeria (Ezekiel, Sulyok, et al., 2012); DON, patulin, and ZEN in maize *fufu* from Cameroon (Abia et al., 2017); and OTA in *garba* from Cote d'Ivoire (West Africa) (Anoman, Koffi, Aboua, & Koussemon, 2018). In some other RTEs, several other mycotoxins, aflatoxins excluded, have also been reported (sometimes in co-occurrence). These include DON in fried maize and popcorn from Indonesia (Asia) (Setyabudi, Nuryono, Wedhastri, Mayer, & Razzazi-Fazeli, 2012), OTA in *garri* from Nigeria (Makun et al., 2013), OTA in biscuits and bread from Pakistan (Majeed, Khaneghah, Kadmic, Khanf, & Shariatig, 2017), and DON, FUM, T-2 toxin and ZEN in *garri* from Nigeria (Chilaka, De Boevre, Atanda, & De Saeger, 2018). A major concern is that many of the RTEs contained mycotoxin levels higher than maximum limits stipulated by the Codex Alimentarius and the European Union.

## 8 | PARASITES IN RTEs FROM LMICs

In addition to the contamination of RTEs by bacteria, fungi, and their toxic metabolites, parasites can also contaminate RTEs (Ayeni, Ofem, Duru, Oyedele, & Ezekiel, 2019; Manyi et al., 2014). Parasitic contamination is usually common in meat-based RTEs. The major contamination sources include the improperly cooked or roasted meat, contaminated water applied to wash the meats, and the slaughter environments. Although not much studies have been conducted in this regard, possibly due to perceived less severity of parasitic infections in humans, it is important to always determine the presence of all potential hazards in foods. This will ensure consumers are protected and they can have confidence in the safety of the foods.

Only two reports were found for the presence of parasites in RTEs in LMICs in the decade under review (Table 4). *Toxoplasma gondii* was reported in barbeque chicken, mutton kebab, and sausages from Egypt (Abd El-Razik et al., 2014), whereas *Ascaris lumbricoides*, *Entamoeba histolytica*, *Giardia lamblia*, and *Taenia* sp. were found in roasted meat (*suya*) in Nigeria (Manyi et al., 2014). Suffice to say that contrary to the perceived less severity of parasitic infections in humans, these infections can be deadly especially when parasites migrate to unwanted body organs or cause perforations of intestinal walls leading to severe complications (Tardieux & Menard, 2008). In addition, the combined risk of acute bacterial infection, chronic mycotoxin exposure, and parasitic infections in affected humans cannot be underestimated. Perhaps one major possible effect of such combined risk may be a contribution to malnutrition and growth faltering in children due to alterations of intestinal/gut integrity by mycotoxins, low assimilation of essential nutrients within the body system as a result of the parasites feeding on required

**TABLE 3** Mycotoxins in ready-to-eat foods from low-and middle-income countries (2009 to 2018)

| Region/Country | Ready-to-eat food | [a]*N* | [b]$N_p$ (%) | LOD(μg/kg) | LOQ(μg/kg) | Mycotoxins | Mean(μg/kg) | Range(μg/kg) | Analytical method | References |
|---|---|---|---|---|---|---|---|---|---|---|
| Africa | | | | | | | | | | |
| Benin | *Kuli kuli* | 45 | ND | NA | NA | $AFB_1$ | ND | 25.5 to 455 | ELISA & LC–MS/MS | Adjou et al., 2012 |
| | | | ND | NA | NA | $AFB_2$ | ND | 33.9 to 491 | ELISA & LC–MS/MS | Adjou et al., 2012 |
| | | | ND | NA | NA | $AFG_1$ | ND | 0.41 to 100 | ELISA & LC–MS/MS | Adjou et al., 2012 |
| | | | ND | NA | NA | $AFG_2$ | ND | 22.0 to 87.7 | ELISA & LC–MS/MS | Adjou et al., 2012 |
| | | | ND | NA | NA | OTA | ND | 0.3 to 2.0 | ELISA & LC–MS/MS | Adjou et al., 2012 |
| Benin | Peanut cake | 15 | 14 (93) | 2 | 6 | $AFB_1$ | ND | <LOQ to 282 | LC/MS–MS | Ediage et al., 2011 |
| | | | 4 (27) | 1 | 4 | $AFB_2$ | ND | <LOQ to 31.0 | LC/MS–MS | Ediage et al., 2011 |
| | | | 10 (67) | 1 | 3 | $AFG_1$ | ND | <LOQ to 79.0 | LC/MS–MS | Ediage et al., 2011 |
| | | | 15 (100) | 0 | 1 | $AFG_2$ | ND | 6.0 to 96.0 | LC/MS–MS | Ediage et al., 2011 |
| | | | 5 (33) | 0.1 | 0.3 | OTA | ND | <LOQ to 2.0 | LC/MS–MS | Ediage et al., 2011 |
| Cameroon | Maize *fufu* | 50 | 12 (24) | 0.15 | 0.5 | $AFB_1$ | 0.9 | ND to 1.8 | LC–MS/MS | Abia et al., 2017 |
| | | | 50 (100) | 3.2 | 10 | $FB_1$ | 151 | 48.0 to 709 | LC–MS/MS | Abia et al., 2017 |
| | | | 50 (100) | 0.8 | 2.6 | DON | 23 | 14.0 to 55.0 | LC–MS/MS | Abia et al., 2017 |
| | | | 15 (30) | 5 | 17 | PAT | 105 | 12.0 to 890 | LC–MS/MS | Abia et al., 2017 |
| | | | 50 (100) | 0.1 | 0.3 | ZEN | 49 | 5.0 to 150 | LC–MS/MS | Abia et al., 2017 |
| Cote d' Ivore | *Garba* | 300 | 170 (57) | 0.00564 | 0.0188 | $AFB_1$ | 3.44 | 0.02 to 35.8 | HPLC | Anoman et al., 2018 |
| | | | 70 (23) | 0.00151 | 0.0050 | $AFB_2$ | 1.90 | 0.10 to 24.0 | HPLC | Anoman et al., 2018 |
| | | | 140 (47) | 0.00136 | 0.0045 | $AFG_1$ | 8.07 | 0.56 to 69.3 | HPLC | Anoman et al., 2018 |
| | | | 120 (40) | 0.00143 | 0.0047 | $AFG_2$ | 0.56 | 0.04 to 13.3 | HPLC | Anoman et al., 2018 |
| | | | 190 (63) | 0.0500 | 0.20 | OTA | 0.42 | 0.06 to 1.83 | HPLC | Anoman et al., 2018 |
| Egypt | Corn based snack | 25 | 10 (40) | NA | 0.5 | $AFB_1$ | 3.85 | 0.59 to 15.8 | HPLC | Amin, Abo-Ghalia, & Hamed, 2010 |
| | | | 1 (4) | NA | 0.5 | $AFB_2$ | 1.98 | 1.98 | HPLC | Amin et al., 2010 |
| Egypt | Hard cheese | 50 | 19 (38) | 50 ng/kg | NA | $AFM_1$ | 132 | 51.6 to 182 | ELISA | Amer & Ibrahim, 2010 |
| | Soft cheese | 50 | 20 (40) | 50 ng/kg | NA | $AFM_1$ | 70.6 | 52.0 to 87.6 | ELISA | Amer & Ibrahim, 2010 |
| | Processed cheese | 50 | 11 (22) | 50 ng/kg | NA | $AFM_1$ | 52.5 | 51.8 to 54.0 | ELISA | Amer & Ibrahim, 2010 |
| Egypt | Fresh *kariesh* cheese | 25 | 8 (32) | NA | NA | $AFM_1$ | 3.6 | 1.95 to 6.11 | Immuno affinity column with flurometric assay | Awad, Amer, Mansour, & Ismail, 2014 |

(Continues)

**TABLE 3** (Continued)

| Region/Country | Ready-to-eat food | [a]*N* | [b]$N_p$ (%) | LOD(μg/kg) | LOQ(μg/kg) | Mycotoxins | Mean(μg/kg) | Range(μg/kg) | Analytical method | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | Damietta cheese | 25 | 12 (48) | NA | NA | $AFM_1$ | 6.7 | 1.54 to 14.7 | Immuno affinity column with flurometric assay | Awad, Amer, Mansour, & Ismail, 2014 |
| Ghana | *Ice-kenkey* | ND | ND | NA | NA | $AFB_1$ | ND | 7.01 to 20.5 | HPLC | Atter, Ofori, Anyebuno, Amoo-Gyasi, & Amoa-Awua, 2015 |
| | | ND | ND | NA | NA | $AFB_2$ | ND | 0.51 to 1.63 | HPLC | Atter et al., 2015 |
| | | ND | ND | NA | NA | $AFG_1$ | ND | 0.0 to 0.47 | HPLC | Atter et al., 2015 |
| Kenya | Roasted coated Peanut | 101 | ND | NA | NA | AFs | 56.5 | 0.0 to 382 | ELISA | Nyirahakizimana et al., 2013 |
| | Roasted de-coated peanut | 49 | ND | NA | NA | AFs | 19.9 | 0.0 to 201 | ELISA | Nyirahakizimana et al., 2013 |
| Kenya | Peanut butter | 12 | 12 (100) | NA | NA | AFs | ND | ND | VICAM AflaTest immunoaffinity fluorometric method | Filbert & Brown, 2012 |
| Malawi | Locally processed peanut butter | 14 | 14 (100) | NA | 0.5 | $AFB_1$ | ND | 13.2 to 40.6 | Immuno-affinity column and reversed phase liquid chromatography | Matumba et al., 2014 |
| | | 14 | 14 (100) | NA | 0.2 | $AFB_2$ | ND | 1.7 to 7.2 | Immuno-affinity column and reversed phase liquid chromatography | Matumba et al., 2014 |
| | De-skinned roasted groundnut | 15 | 11 (73) | NA | 0.5 | $AFB_1$ | ND | 0.1 to 12.3 | Immuno-affinity column and reversed phase liquid chromatography | Matumba et al., 2014 |
| | | 15 | 10 (67) | NA | 0.2 | $AFB_2$ | ND | 0.2 to 1.8 | Immuno-affinity column and reversed phase liquid chromatography | Matumba et al., 2014 |
| Nigeria | Corn based snack | 3 | 3 (100) | NA | NA | $AFB_1$ | 14 | 6.0 to 30.0 | Thin Layer Chromatography (TLC) | Ezekiel, Kayode, Fapohunda, Olorunfemi, & Kponi, 2012 |

(Continues)

**TABLE 3** (Continued)

| Region/Country | Ready-to-eat food | [a]*N* | [b]$N_p$ (%) | LOD(μg/kg) | LOQ(μg/kg) | Mycotoxins | Mean(μg/kg) | Range(μg/kg) | Analytical method | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $AFB_2$ | 8.0 | ND | TLC | Ezekiel, Kayode, et al., 2012 |
| | | | | | | $AFG_1$ | 6.0 | ND | TLC | Ezekiel, Kayode, et al., 2012 |
| | Groundnut based snack | 12 | 9 (75) | NA | NA | $AFB_1$ | 8.5 | 0.0 to 12.5 | TLC | Ezekiel, Kayode, et al., 2012 |
| | | | | | | $AFB_2$ | 9.0 | 0.0 to 9.0 | TLC | Ezekiel, Kayode, et al., 2012 |
| | | | | | | $AFG_1$ | 15.8 | 0.0 to 31.3 | TLC | Ezekiel, Kayode, et al., 2012 |
| | Nut-based snack | 5 | 1 (20) | NA | NA | $AFB_1$ | 6.0 | ND | TLC | Ezekiel, Kayode, et al., 2012 |
| | Wheat-based snack | 5 | 4 (80) | NA | NA | $AFB_1$ | 17.8 | 0.0 to 50.0 | TLC | Ezekiel, Kayode, et al., 2012 |
| | | | | | | $AFG_1$ | 13 | ND | TLC | Ezekiel, Kayode, et al., 2012 |
| Nigeria | Peanut cake | 29 | 29 (100) | 2.0 | NA | $AFB_1$ | ND | ND to 2820 | LC/ESI–MS/MS | Ezekiel, Sulyok, et al., 2012 |
| | | | 29 (100) | 0.02 | NA | BEAU | ND | ND | LC/ESI–MS/MS | |
| | | | 4 (14) | 4.0 | NA | OTA | ND | ND | LC/ESI–MS/MS | |
| Nigeria | *Kokoro* | 16 | 8 (50) | NA | NA | $AFB_1$ | ND | 0.75 to 7.25 | ELISA | Onifade, Adesokan, & Adebayo-Tayo, 2014 |
| Nigeria | Roasted groundnut | 22 | 21 (96) | 2 | NA | $AFB_1$ | 14.1 | 1.3 to 59.1 | High-Performance Thin Layer Chromatography (HPTLC) | Afolabi et al., 2015 |
| | | | 18 (82) | 2 | NA | tAF | 23.9 | 1.3 to 134 | HPTLC | Afolabi et al., 2015 |
| Nigeria | Roasted cashew nut | 27 | ND | NA | NA | AF | ND | 0.1 to 6.8 | ELISA | Adetunji, Alika, Awa, Atanda, & Mwanza, 2018 |
| Nigeria | Roasted groundnut | 10 | 6 (60) | NA | NA | tAF | ND | 1.20 to >20.0 | ELISA | Ubwa et al., 2014 |
| | Roasted cashew nut | 10 | 2 (20) | NA | NA | tAF | ND | 0.10 to 0.40 | ELISA | Ubwa et al., 2014 |
| Nigeria | *Garri* | 18 | 18 (100) | 0.001 | NA | OTA | 7.63 | 3.28 to 22.7 | HPLC | Makun et al., 2013 |
| Nigeria | *Garri* | 24 | 9 (38) | 14.5 | 29.0 | DON | 57 | 35.0 to 99.0 | LC–MS/MS | Chilaka et al., 2018 |
| | | | 6 (25) | 15.0 | 30.0 | $FB_1$ | 60 | 45.0 to 80.0 | LC–MS/MS | Chilaka et al., 2018 |
| | | | 5 (21) | 10.5 | 21.1 | $FB_2$ | 40 | 29.0 to 65.0 | LC–MS/MS | Chilaka et al., 2018 |
| | | | 3 (13) | 4.5 | 9.1 | T-2 | 19 | 17.0 to 22.0 | LC–MS/MS | Chilaka et al., 2018 |

(Continues)

**TABLE 3** (Continued)

| Region/Country | Ready-to-eat food | [a]*N* | [b]$N_p$ (%) | LOD(μg/kg) | LOQ(μg/kg) | Mycotoxins | Mean(μg/kg) | Range(μg/kg) | Analytical method | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 (17) | 3.6 | 7.2 | ZEN | 14 | 11.0 to 17.0 | LC–MS/MS | Chilaka et al., 2018 |
| Nigeria | *Aadun* | 5 | 5 (100) | NA | NA | $AFB_1$ | ND | 3.4 to 12.8 | HPLC | Jonathan et al., 2015 |
| | | | | NA | NA | $AFB_2$ | ND | 2.8 to 3.2 | HPLC | Jonathan et al., 2015 |
| | | | | | | $AFG_1$ | ND | 1.7 to 3 | HPLC | Jonathan et al., 2015 |
| | | | | NA | NA | $AFG_2$ | ND | 1.6 to 3.2 | HPLC | Jonathan et al., 2015 |
| Nigeria | Sausage roll | 4 | 4 (100) | NA | NA | $AFB_1$ | ND | 1.08 to 1.88 | HPLC/MS | Jonathan, Okoawo, & Asemoloye, 2016 |
| | | | | NA | NA | $AFB_2$ | ND | 0.99 to 1.98 | HPLC/MS | Jonathan et al., 2016 |
| | | | | NA | NA | $AFG_1$ | ND | 0.92 to 1.23 | HPLC/MS | Jonathan et al., 2016 |
| | | | | NA | NA | $AFG_2$ | ND | 0.91 to 1.73 | HPLC/MS | Jonathan et al., 2016 |
| Sierra Leone | Roasted peanut | 50 | 8 (16) | 0.24 | 0.79 | $AFB_1$ | 178 | 0.62 to 1,387 | LC–MS/MS | Sombie et al., 2018 |
| | | | 3 (6) | 0.4 | 1.3 | $AFB_2$ | 96.4 | 6.49 to 271 | LC–MS/MS | Sombie et al., 2018 |
| | | | 12 (24) | 0.32 | 1.1 | $AFG_1$ | 281 | 0.34 to 3,328 | LC–MS/MS | Sombie et al., 2018 |
| | | | 2 (4) | 0.8 | 2.6 | $AFG_2$ | 378 | 14.7 to 742 | LC–MS/MS | Sombie et al., 2018 |
| | | | 2 (4) | 0.4 | 1.3 | $AFM_1$ | 34 | 1.22 to 66.8 | LC–MS/MS | Sombie et al., 2018 |
| Sudan | Peanut butter | 43 | 28 (65) | 1.5 | NA | $AFB_1$ | 223 | 73.9 to 534 | HPLC | Elzupir, Salih, Suliman, Adam, & Elhussein, 2011 |
| | | | 42 (98) | 0.09 | NA | $AFB_2$ | 3.2 | 0.18 to 23.9 | HPLC | Elzupir et al., 2011 |
| | | | 43 (100) | 0.8 | NA | $AFG_1$ | 137 | 26.5 to 401 | HPLC | Elzupir et al., 2011 |
| | | | 4 (9) | 0.4 | NA | $AFG_2$ | 18.5 | 8.60 to 30.1 | HPLC | Elzupir et al., 2011 |
| | | | 43 (100) | NA | NA | tAF | 287 | 26.6 to 853 | HPLC | Elzupir et al., 2011 |
| Zambia | Peanut butter | 109 | 100 (92) | NA | NA | AFs | 18.9 | 1.75 to 147 | CD–ELISA | Banda, Likwa, Bwembya, Banda, & Mbewe, 2018 |
| Zimbabwe | Peanut butter | 11 | 10 (91) | NA | NA | $AFB_1$ | 51 | 3.7 to 191 | HPLC | Mupunga, Lebelo, Mngqawa, Rheeder, & Katerere, 2014 |

(Continues)

**TABLE 3** (Continued)

| Region/Country | Ready-to-eat food | [a]*N* | [b]$N_p$ (%) | LOD(μg/kg) | LOQ(μg/kg) | Mycotoxins | Mean(μg/kg) | Range(μg/kg) | Analytical method | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 (36) | NA | NA | $AFB_2$ | ND | 6.2 to 25.7 | HPLC | Mupunga et al., 2014 |
| | | | 5 (45) | NA | NA | $AFG_1$ | ND | 9.3 to 47.1 | HPLC | Mupunga et al., 2014 |
| | | | 1 (9) | NA | NA | $AFG_2$ | ND | 0 to 8.8 | HPLC | Mupunga et al., 2014 |
| | | | 10 (91) | NA | NA | tAF | 75.7 | 6.1 to 247 | HPLC | Mupunga et al., 2014 |
| Asia | | | | | | | | | | |
| India | Chilgoza pine nuts | 58 | 11 (19) | NA | NA | $AFB_1$ | 0.91 | 0.73 to 1.64 | TLC & HPLC | Sharma, Gupta, & Sharma, 2013 |
| | | | 13 (22) | NA | NA | $AFB_2$ | 1.01 | 0.70 to 2.26 | TLC & HPLC | Sharma et al., 2013 |
| India | Jam | 40 | 20 (50) | NA | NA | $AFB_1$ | ND | 1.52 to 183 | HPLC | Nair, Ghadevaru, Manimehali, & Athmaselvi, 2015 |
| Indonesia | Popcorn | 7 | 7 (100) | 20 | NA | DON | 127 | 59.9 to 202 | HPLC–UV | Setyabudi, Nuryono, Wedhastri, Mayerm, & Fazeli, 2012 |
| | Fried maize | 9 | 9 (100) | 20 | NA | DON | 155 | 67.1 to 348 | HPLC–UV | Setyabudi et al., 2012 |
| Pakistan | Biscuit | 10 | 3 (20) | 0.01 | 0.02 to 0.05 | tAF | ND | 0.04 to 2.28 | RP–HPLC | Mushtaq, Sultana, Anwar, Khan, & Ashrafuzzaman, 2012 |
| | Bread slice | 3 | 1 (33) | 0.01 | 0.02 to 0.05 | tAF | ND | 0.1 to 0.26 | RP–HPLC | Mushtaq et al., 2012 |
| Pakistan | Biscuit | 5 | 2 (40) | NA | NA | OTA | 23.9 | ND to 360 | LC | Majeed et al., 2017 |
| | Bread | 5 | 3 (60) | NA | NA | OTA | 1.96 | ND to 4.66 | LC | Majeed et al., 2017 |
| The Caribbean | | | | | | | | | | |
| Haiti | Peanut butter | 18 | 16 (89) | NA | NA | AFs | ND | ND | VICAM AflaTest immunoaffinity fluorometric method | Filbert & Brown, 2012 |

Abbreviations: NA, not applicable; ND, no data; LOD, limit of detection; LOQ, limit of quantification; $AFB_1$, aflatoxin $B_1$; $AFB_2$, aflatoxin $B_2$; $AFG_1$, aflatoxin $G_1$; $AFG_2$, aflatoxin $G_2$, AF, aflatoxins; tAF, total aflatoxin, $AFM_1$, aflatoxin $M_1$, OTA, ochratoxin; FUM, fumonisin; DON, deoxynivalenol; PAT, patulin; ZEN, zearalenone; TLC, thin layer chromatography; LC–MS/MS, liquid chromatography–tandem mass spectrometry; HPLC, high-performance liquid chromatography, ELISA, enzyme linked immunosorbent assay; LC/ESI–MS/MS, liquid chromatography/electrospray ionization–tandem mass spectrometric; RP-HPLC, reverse-phase high-performance liquid chromatography.

[a]Number of samples

[b]Number of positive samples

**TABLE 4** Parasites reported in ready-to-eat (RTE) foods in low- and middle-income countries (2009 to 2018)

| Region | Country | RTE food | Potential source of contamination | Parasite | Analytical method | References |
|---|---|---|---|---|---|---|
| Africa | Egypt | Barbeque chicken | Insufficient cooking | *Toxoplasma gondii* | PCR | Abd El-Razik et al., 2014 |
| | | Mutton kebab | Insufficient cooking | *T. gondii* | PCR | Abd El-Razik et al., 2014 |
| | | Sausage | Insufficient cooking | *T. gondii* | PCR | Abd El-Razik et al., 2014 |
| | Nigeria | *Suya* | Lack of potable water for processing | *Ascaris lumbricoides*, *Entamoeba histolytica*, *Taenia* sp., and *Giardia lamblia* | Microscopy | Manyi et al., 2014 |

nutrients for child growth, and gastroenteropathy from severe foodborne bacterial infections in the gut; this postulation needs verification. Furthermore, it is pertinent to mention that compared to bacterial and fungal identification, parasites can be characterized with less sophisticated techniques (such as light microscopy; Cheesbrough, 1998). Thus, more reports on this foodborne hazard are expected in the future from LMICs where access to high-end molecular equipment (such as polymerase chain reaction and sequencers) may not be fully available.

## 9 | VIRUSES IN RTEs FROM LMICs

Notable foodborne viruses include hepatitis A and E, norovirus, and rotavirus (FAO/WHO, 2008; Maunula, & von Bonsdorff, 2016; Stals, Baert, Van Coillie, & Uyttendaele, 2012). These viruses are well equipped with machineries to withstand environmental stressors in food matrices. These stressors include extreme pH, harsh food processing and storage conditions (such as heat, freezing, and exposure to organic acids), and persistence in food contact surfaces (for example, stainless steel) (Hewitt & Greening, 2004; Koopmans, & Duizer, 2004; Lamhoujeb, Fliss, Ngazoa, & Jean, 2009). Unlike pathogenic bacteria, fungi, and parasites, foodborne viruses are obligate intracellular parasites, thus are incapable of replicating in an inert environment like food matrices (Koopmans, & Duizer, 2004). Thus, the viral load at the point of contamination is unlikely to increase (Koopmans, & Duizer, 2004; Newell et al., 2010). Nonetheless, low viral doses are required to cause an infection (Maunula, & von Bonsdorff, 2016), as such, viruses are a major concern to food safety.

Regarding the occurrence of viruses in RTEs from LMICs in the decade under review, we found only one report on the presence of hepatitis A virus in flour- and/or meat-based meal from Cameroon (Table 5; Yongsi, 2018). Obvious reasons for this paucity of data could be the lack of skilled expertise required for the detection of viruses in RTEs in LMICs, low amount of viruses present in foods, which makes detection very difficult, and variability of methods applied for different food matrices (Koopmans, & Duizer, 2004; Maunula, & von Bonsdorff, 2016). Nevertheless, several reports on human exposure to foodborne viruses in some LMICs via detection of these viruses in biological samples, for example, stool (Ayukekbong et al., 2011; Kumar, Basu, Vashishtha, & Choudhury, 2016; Mans, 2019; Mattison, Sebunya, Shukla, Noliwe, & Bidawid, 2010; Mukherjee et al., 2010; Omore et al., 2019) and blood (Chadha, Lole, Bora, & Arankalle, 2009; Teshale et al., 2010), suggest that humans are frequently exposed to foodborne viruses in LMICs.

Currently, norovirus and rotavirus rank among the leading cause of diarrheal-related deaths in humans particularly children in LMICs (Kirk et al., 2015a, 2015b; Lopman, Steele, Kirkwood, & Parashar, 2016; Mans, 2019; Parashar et al., 2009; Taneja & Malik, 2012). It is important to mention that rotavirus vaccines are now available and have been included in the national immunization programs in some LMICs (Patel, Glass, Desai, Tate, & Parashar, 2012; Shah, Tate, Mwenda, Steele, & Parashar, 2017). Furthermore, administration of these vaccines in humans has yielded some positive results as revealed in a few studies that reported reduction in human exposure to rotavirus in some LMICs (Armah et al., 2016; Bar-Zeev et al., 2015; Schwartz et al., 2019). Notwithstanding, rotavirus vaccines are not yet widely available in some LMICs (Motayo, Faneye, & Adeniji, 2018; Sindhu, Babji, & Ganesan, 2017). Contrary to the case of rotavirus, development of norovirus vaccines is still ongoing (Hallowell, Parashar, & Hall, 2018; Riddle, Chen, Kirkwood, & MacLennan, 2018), and thus a licensed norovirus vaccine is currently unavailable (Huys, Grau, & Karst, 2020). Taken together, indications are that these two viruses and other foodborne viruses could continually pose a threat to RTE consumers in LMICs. Consequently, in the interim, it is pertinent that in addition to screening for the presence of bacteria, fungi, and parasites in RTEs, food surveillance studies in LMICs should include the detection of viruses. This will provide data for relevant government agencies and policy makers to enact policies and drive regulations concerning foodborne viruses in RTEs.

**TABLE 5** Virus reported in ready-to-eat (RTE) foods in low- and middle-income countries (2009 to 2018)

| Region | Country | RTE food | Potential source of contamination | Virus | Analytical method | References |
|---|---|---|---|---|---|---|
| Africa | Cameroon | Flour and meat based | Poor hygiene practices | Hepatitis A virus | Direct flocculation and NASBA | Yongsi, 2018 |

NASBA, nucleic acid sequence-based amplification

## 10 | FOOD SAFETY SOLUTIONS AND FUTURE PERSPECTIVES

The search for interventions geared toward ensuring the safety of foods, RTEs inclusive, globally has been marked with successes as well as challenging efforts (FAO/WHO, 2018). Nevertheless, to make RTEs safe for consumers in LMICs, there is a need to adopt a holistic approach, which involves intervening in the areas highlighted below. Major factors to consider in proposing interventions for mitigating foodborne hazards in LMICs include the feasibility of the interventions considering the low-income status of greater population in the countries, sanitation and environmental conditions in the countries, and low awareness of the food safety issue as it affects human health among processors, vendors, and consumers of RTEs.

### 10.1 | Integration of control approaches

There is a need to focus interventions at the entire value chain, beginning from farm to fork. For example, a set of good pre- and postharvest practices has been suggested to reduce mycotoxin contamination of cereals and nuts that serve as RTE ingredients (Bandyopadhyay et al., 2016; Ezekiel et al., 2018). These practices include crop rotation, irrigation in areas of drought, timely harvesting, proper drying to safe moisture levels, sorting out the visibly discolored, infected and damaged grains, and storage in appropriate conditions to avoid moisture rise and insect infestation. In addition, good transport systems are essential to ensure the safety of grains moved within the different parts of the LMICs (Grace, 2015). To be specific, in many LMICs there are lack of good road networks connecting grain producing communities to municipal cities. The vehicles utilized for transport of the grains are also of low quality (often uncleaned). These factors need attention in order to reduce RTE contamination. In addition, it has been suggested that oxygenated tanks may be used to transport fresh fish alive to the point of sale (Grace, 2017). Access to portable water sources is also crucial to ensuring food safety especially in rural communities where the low-income households and food processors reside. Proper RTE storage facilities (for example, cold temperature) could also be useful to keep pathogenic microorganisms away (Kunadu, Ofosu, Aboagye, & Tano-Debrah, 2016). In addition, bacteriophages could be used as biocontrol agents against notorious psychrophilic foodborne pathogens such as *Listeria* spp. (Chibeu, 2013). Furthermore, there should be increased awareness on public health issues surrounding contaminated foods by educating food processors, vendors, and consumers on effective food handling, good personal hygiene, good handling, and processing practices. The advocacy and awareness efforts should also target policy makers and high-level government officials and should focus on their commitments and roles to providing those they govern and protect with basic amenities to enhance food safety and protect consumer health.

### 10.2 | Effective surveillance and monitoring of foodborne pathogens in RTEs

Surveillance and monitoring exercises aimed at identifying foodborne hazards are major steps toward the prevention and control FBD. Such program, if effectively executed, could bridge some enlightenment gaps among food vendors and processors depending on the food sampling points. Thus, it is imperative that regulatory officials effectively monitor RTEs for the presence of pathogenic microorganisms and their toxins before they are allowed in the market. However, monitoring at the local market in remote area may be a heinous task. One approach to tackle this problem is to increase food safety awareness and education; that is, mainstream food safety courses into the educational curriculum at the basic (primary) and high school (secondary) levels.

The quality of techniques applied during the surveillance studies is also crucial for proper risk assessment. Investments focused on building cutting-edge infrastructures in LMICs for proper monitoring of RTEs should be prioritized. Such advanced infrastructures will gradually erode the application of conventional techniques (such as, culture-based microbial isolations and thin-layer chromatography for toxin detection). Rapid techniques involving immunoassays and nucleic acid-based methods for foodborne pathogen detection (Lee et al., 2015) and liquid chromatography–mass spectrometric methods for microbial toxin analysis (Berthiller et al., 2017) should be adopted to enable accurate and high-throughput analysis.

### 10.3 | Building food safety expertise for monitoring and control of food contaminants in LMICs

It is crucial to invest in training researchers and food regulatory officers on modern technologies to detect microbial

contaminants in RTEs in order to ensure proper surveillance and source tracking. This can be achieved through collaborations between relevant government agencies and research institutions in LMICs, as well as between food safety experts in LMICs and those in the economically developed world (Europe and North America). Forms of collaborations may include staff and student exchange for technology transfer, short training programs/fellowships, collaborative funding/grant acquisition for establishment of functional food safety centers equipped with state-of-the-art equipment in LMICs, as well as donation of equipment to LMICs. Country governments are also urged to prioritize food safety and thus invest in cutting-edge infrastructure and human capacity building for effective prevention and control of FBD as well as consumer protection.

Building expertise for food safety should also be viewed on the scope of the value chain. Consequently, farmers, food handlers, processors, and vendors should be educated on food safety regulations and standards. For example, they could be encouraged to form cooperative and industrial societies geared toward acquiring relevant skills and training to ensure good agricultural and processing practices, which may positively influence food safety (Kumar, Parappurathu, & Jee, 2013). In addition, there should be requisite infrastructures and good welfare packages to enable all relevant stakeholders carry out effective monitoring and control of food contaminants.

### 10.4 | Regulations: Setting and enforcement

Any need for regulations regarding RTEs (on-shelf and off-shelf) in LMICs? Would this impact negatively on food security? If it would, do we then prioritize food safety over food availability? The obvious answer should be YES! These are the obvious set of questions bugging the minds of food safety regulators in LMICs and militating against the establishment of regulations targeting RTEs, especially the locally produced ones. Taking a look at food production in some LMICs, it is observable that most LMICs conveniently produce in large quantities the raw ingredients (for example, cereals, nuts, and tubers) for RTEs. Obviously, the major problem with establishing regulations is not the availability of these foods, but how to ensure their safety. Thus, it is crucial to ensure the microbiological safety of these foods, which will help sustain food security. Consequently, there should be strict regulations guiding the production and sale of RTE ingredients and their finished products in countries where regulations are nonexistent. Where food regulations do exist, appropriate measures must be in place to enforce them. The regulations should cover all aspects of food safety and include the quality of ingredients, strict personal hygiene standards for RTE vendors (including routine health checks and certification from recommended health facilities), periodic inspection standards for all RTE retail points, and definition of acceptable standards for RTEs (for example, water quality standards, standard packaging materials, and vending sites/locations).

### 10.5 | Protection of consumer rights

Consumer demand for RTEs is high in LMICs; hence, consumers should be made aware of what to look out for in these foods and insist on details of processed RTEs to be provided. These will afford consumers the opportunity to make informed decisions on their choices of RTEs, thereby taking the first steps toward safeguarding their health. Consumer enlightenment can be achieved through various means such as soapboxes, the media, internet platforms (where available), and workshops. Education via the media and internet platforms could be useful tools for consumers in the urban and suburban areas owing to wider coverage and ability to transmit information to several people in a relatively short period (Jabbar, Baker, & Fadiga, 2010). However, in rural communities where media and internet facilities maybe unavailable, trainings involving major community stakeholders, for example, community heads and chiefs and local households, could be organized to disseminate such crucial information. Beyond being aware about the safety of RTEs, the government via relevant agencies in LMICs should enact and sustain policies to protect consumer rights. In addition, in cases of food fraud, consumers should be properly compensated, and strict penalties should be meted out to the defaulting food processor and/or vendor.

## 11 | CONCLUSION

This comprehensive review paper has presented robust data on the spectra of RTEs in LMICs, sources of microbial contamination of RTEs in the regions, techniques for detecting the microbial contaminants as well as the occurrences of various RTE contaminants of microbial origin. The paper has shown that RTEs are important food sources for a large set of the populations in LMICs due to the food diversity and ease of acquisition. However, these foods constitute a high-risk set of foods due to poor personal hygiene of processors, poverty, lack of insights and knowledge into the adverse health effects that could arise from consumption of contaminated foods, and nonexistent or inadequately enforced regulations. To tackle the challenge, we proposed a set of integrated and feasible food safety solutions and future perspectives tailored for LMICs in order to ensure safety of RTEs and protection of public health. These include, but not limited to, adoption of good agricultural, good processing and handling practices, effective surveillance and monitoring along the RTE chain, establishment and enforcement of regulations, capacity building of food safety experts, and enlightenment of the public (RTE processors, vendors, consumers, and government

officials) on the following: dangers of consuming contaminated foods, strategies to avoid food contamination and enhance food safety, and their obligations to ensure the foods they consume are safe.

## AUTHOR CONTRIBUTIONS

Conception of idea: C.N.E. Design of review outline: O.M.M. and C.N.E. Drafting and reviewing of study outline: O.M.M., K.I.A., R.A.A., and C.N.E. Sourcing literature: O.M.M. and K.I.A. Data compilation and preparation of tables: O.M.M., K.I.A., and C.N.E. Interpretation of data, preparation, and fine-tuning of draft manuscript: O.M.M., K.I.A., M.S., R.K., R.A.A., and C.N.E.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## ORCID

*Michael Sulyok* https://orcid.org/0000-0002-3302-0732
*Chibundu N. Ezekiel*
https://orcid.org/0000-0002-2113-2948

## REFERENCES

Abd El-Razik, K. A., El Fadaly, H. A., Barakat, A. M. A., & Abu Elnaga, A. S. M. (2014). Zoonotic hazards *T. gondii* viable cysts in ready to eat Egyptian meat-meals. *World Journal of Medical Sciences*, *11*(4), 510–517.

Abdallah, M. S., & Mustafa, N. E. M. (2010). Bacteriological quality of street-vended Um-Jingir: A traditional Sudanese Food. *Internet Journal of Food Safety*, *12*, 16–19.

Abia, W. A., Warth, B., Ezekiel, C. N., Sarkanj, B., Turner, P. C., Marko, D., … Sulyok, M. (2017). Uncommon toxic microbial metabolite patterns in traditionally home-processed maize dish (*fufu*) consumed in rural Cameroon. *Food and Chemical Toxicology*, *107*, 10–19.

Abia, W. A., Warth, B., Sulyok, M., Krska, R., Tchana, A. N., Njobeh, P. B., … Moundipa, P. F. (2013). Determination of multi-mycotoxin occurrence in cereals, nuts and their products in Cameroon by liquid chromatography tandem mass spectrometry (LC-MS/MS). *Food Control*, *31*, 438–453.

Adebayo-Oyetoro, A. O., Ogundipe, O. O., Lofinmakin, F. K., Akinwande, F. F., Aina, D. O., & Adeyeye, S. A. O. (2017). Production and acceptability of *chin chin* snack made from wheat and tigernut (*Cyperus esculentus*) flour. *Cogent Food & Agriculture*, *3*(1), 1282185.

Adetunji, M. C., Alika, O. P., Awa, N. P., Atanda, O. O., & Mwanza, M. (2018). Microbiological quality and risk assessment for aflatoxins in groundnuts and roasted cashew nuts meant for human consumption. *Journal of Toxicology*, *2018*, 1–11.

Adetunji, M. C., Atanda, O. O., Ezekiel, C. N., Sulyok, M., Warth, B., Beltran, E., … Chilaka, C. A. (2014). Fungal and bacterial metabolites of stored maize (*Zea mays*, L.) from five agro-ecological zones of Nigeria. *Mycotoxin Research*, *30*(2), 89–102.

Adewumi, G. A., Oguntoyinbo, F. A., Keisam, S., Romi, W., & Jeyaram, K. (2013). Combination of culture-independent and culture-dependent molecular methods for the determination of bacterial community of *iru*, a fermented *Parkia biglobosa* seeds. *Frontiers in Microbiology*, *3*, 1–9.

Adeyeye, S. A. O. (2017). "A preliminary study on the quality and safety of street vended *warankasi* (a Nigerian soft white cheese) from Ibadan, Oyo state, Nigeria". *British Food Journal*, *119*(2), 322–330.

Adio, H. I., Ovuoraini, E. H., & Olubunmi, A. E. (2014). Microbial quality of ready to eat barbecue meat (*suya*) sold on the streets of Lagos State. *International Journal of Advances in Pharmacy, Biology and Chemistry*, *3*(4), 973–982.

Adjou, E. S., Yehouenou, B., Sossou, C. M., Soumanou, M. M., & De Souza, C. A. (2012). Occurrence of mycotoxins and associated mycoflora in peanut cake product (*kulikuli*) marketed in Benin. *African Journal of Biotechnology*, *11*(78), 14354–14360.

Adjrah, Y., Soncy, K., Anani, K., Blewussi, K., Karou, D. S., Ameyapoh, Y., … Gbeassor, M. (2013). Socio-economic profile of street food vendors and microbiological quality of ready-to-eat salads in Lomé. *International Food Research Journal*, *20*(1), 65–70.

Adolf, J. N. P., & Azis, B. S. (2012). Microbiological status of various foods served in elementary school based on social economic status differences in Karawaci Region, Tangerang District – Indonesia. *International Food Research Journal*, *19*(1), 65–70.

Afolabi, C. G., Ezekiel, C. N., Kehinde, I. A., Olaolu, A. W., & Ogunsanya, O. M. (2015). Contamination of groundnut in South-western Nigeria by aflatoxigenic fungi and aflatoxins in relation to processing. *Journal of Phytopathology*, *163*, 279–286.

Agrawal, A., Gupta, R., & Varma, K. (2008). High trans fatty acid content in common Indian fast foods. *Nutrition & Food Science*, *38*(6), 564–569.

Agwa, O. K., Ossai-Chidi, L. N., & Ezeani, C. A. (2014). Microbial evaluation of orange fruit juice sold in Port Harcourt, Nigeria. *American Journal of Food Science and Nutrition Research*, *1*(5), 28–33.

Al Mamun, M., Rahman, S. M. M., & Turin, T. C. (2013a). Microbiological quality of selected street food items vended by school-based street food vendors in Dhaka, Bangladesh. *International Journal of Food Microbiology*, *166*(3), 413–418.

Al Mamun, M., Rahman, S. M. M., & Turin, T. C. (2013b). Knowledge and awareness of children's food safety among school-based street food vendors in Dhaka, Bangladesh. *Foodborne Pathogens and Disease*, *10*(4), 323–330.

Alcaine, S. D., Sukhnanand, S. S., Warnick, L. D., Su, W. L., McGann, P., McDonough, P., & Wiedmann, M. (2005). Ceftiofur-resistant *Salmonella* strains isolated from dairy farms represent multiple widely distributed subtypes that evolved by independent horizontal gene transfer. *Antimicrobial Agents and Chemotheraphy*, *49*, 4061–4067.

Alimi, B. A. (2016). Risk factors in street food practices in developing countries: A review. *Food Science and Human Wellness*, *5*, 141–148.

Amer, A. A., & Ibrahim, M. A. E. (2010). Determination of aflatoxin $M_1$ in raw milk and traditional cheeses retailed in Egyptian markets. *Journal of Toxicology and Environmental Health Sciences*, *2*(4), 50–53.

Amin, A. A., Abo-Ghalia, H. H., & Hamed, A. A. (2010). Aflatoxin $B_1$ and $B_2$ in cereal – based baby foods and corn-based snacks from Egypt markets: Occurrence and estimation of the daily intake of $AFB_1$. *The African Journal of Mycology and Biotechnology*, *15*, 1–11.

Ankita, B., Prasad, Y., & Umesh, P. S. (2012). Microbial contamination of food available in Sub metropolitan city Birgunj in Nepal and

its effect on human health. *International Journal of BioSciences and Technology*, *5*(15), 82–87.

Annan-Prah, A., Amewowor, D. H. A. K., Osei-Kofi, J., Amoono, S. E., Akorli, S. Y., Saka, E., & Ndadi, H. A. (2011). Street foods: Handling, hygiene and client expectations in a World Heritage Site Town, Cape Coast, Ghana. *African Journal of Microbiology Research*, *5*, 1629–1634.

Anoman, A. T., Koffi, K. M., Aboua, K. N., & Koussemon, M. (2018). Determination of ETM, histamine and mycotoxins in *garba*, a traditional ivoirian meal. *American Journal of Analytical Chemistry*, *9*, 245–256.

Argudin, M. A., Mendoza, M. C., & Rodicio, M. R. (2010). Food poisoning and *Staphylococcus aureus* enterotoxins. *Toxins*, *2*, 1751–1773.

Armah, G., Pringle, K., Enweronu-Laryea, C. C., Ansong, D., Mwenda, J. M., Diamenu, S. K., … Lopman, B. (2016). Impact and effectiveness of monovalent rotavirus vaccine against severe rotavirus diarrhea in Ghana. *Clinical Infectious Diseases*, *62*, S200–S207.

Aruwa, C. E., & Ogunlade, S. T. (2016). Classical identification, 16S rDNA sequencing, and molecular characterization of Bacillus species from convenience foods. *British Journal of Applied Science & Technology*, *15*(5), 1–11.

Atter, A., Ofori, H., Anyebuno, G. A., Amoo-Gyasi, M., & Amoa-Awua, W. K. (2015). Safety of a street vended traditional maize beverage, *ice-kenkey*, in Ghana. *Food Control*, *55*, 200–205.

Awad, E. I., Amer, H. I., Mansour, H., & Ismail, S-E. Y. (2014). Qualitative and quantitative detection of aflatoxin $M_1$ residues in white soft cheese. *Alexandria Journal of Veterinary Sciences*, *40*, 119–123.

Ayalew, A., Hoffmann, V., Lindahl, J., & Ezekiel, C. N. (2016). The role of mycotoxin contamination in nutrition: The aflatoxin story. In N. Covic & S. L. Hendriks (Eds.), *Achieving a nutrition revolution for Africa: The road to healthier diets and optimal nutrition* (pp. 98–114). Washington, DC: International Food Policy Research Institute.

Ayeni, K. I., Ofem, G. O., Duru, I. F., Oyedele, A. O., & Ezekiel, C. N. (2019). A mini-survey of pathogenic bacteria and parasites in *suya* meat vended in Ilishan Remo, Ogun State. *Acta SATECH*, *11*(1), 62–68.

Ayukekbong, J., Lindh, M., Nenonen, N., Tah, F., Nkuo-Akenji, T., & Bergström, T. (2011). Enteric viruses in healthy children in Cameroon: Viral load and genotyping of norovirus strains. *Journal of Medical Virology*, *83*(12), 2135–2142.

Banda, M. S., Likwa, R. N., Bwembya, P., Banda, J., & Mbewe, A. (2018). Consumption of aflatoxin contaminated peanut butter: A health threat to the population in Lusaka urban Zambia. *Food and Environment Safety*, *17*(3), 317–326.

Bandyopadhyay, R., Ortega-Beltran, A., Akande, A., Mutegi, C., Atehnkeng, J., Kaptoge, L., … Cotty, P. J. (2016). Biological control of aflatoxins in Africa: Current status and potential challenges in the face of climate change. *World Mycotoxin Journal*, *9*(5), 771–789.

Bankole, S., Schollenburger, M., & Drochner, W. (2006). Mycotoxins in food systems in sub Saharan Africa: A review. *Mycotoxin Research*, *22*(3), 163–169.

Bardi, M., Burbank, A., Choi, W., Chow, L., Jang, W., Roccamatisi, D., … Macnab, A. J. (2014). Activities for engaging schools in health promotion. *Health Education*, *114*(4), 271–280.

Bar-Zeev, N., Kapanda, L., Tate, J. E., Jere, K. C., Iturriza-Gomara, M., Nakagomi, O., … Cunliffe, N. A. (2015). Effectiveness of a monovalent rotavirus vaccine in infants in Malawi after programmatic roll-out: An observational and case-control study. *The Lancet Infectious Diseases*, *15*(4), 422–428.

Batool, S. A., Tahir, S. S., Rauf, N., & Kalsoom, R. (2013). Microbiological analysis of pasteurized and fresh fruit juice sold in Rawalpindi of Pakistan. *Bangladesh Journal of Scientific and Industrial Research*, *48*(3), 185–192.

Beisl, J., Pahlke, G., Abeln, H., Ehling-Schulz, M., DelFavero, G., Varga, E., … Marko, D. (2019). Combinatory effects of cereulide and deoxynivalenol on *in vitro* cell viability and inflammation of human Caco-2 cells. *Archives of Toxicology*.

Benkerroum, N. (2013). Traditional fermented foods of North African Countries: Technology and food safety challenges with regard to microbiological risks. *Comprehensive Reviews in Food Science and Food Safety*, *12*(1), 54–89.

Berthiller, F., Brera, C., Iha, M. H., Krska, R., Lattanzio, V. M. T., MacDonald, S., … Tittlemier, S. A. (2017). Developments in mycotoxin analysis: An update for 2015–2016. *World Mycotoxin Journal*, *10*(1), 5–29.

Berthiller, F., Cramer, B., Iha, M. H., Krska, R., Lattanzio, V. M. T., MacDonald, S., … Tittlemier, S. A. (2018). Developments in mycotoxin analysis: An update for 2016–2017. *World Mycotoxin Journal*, *11*(1), 5–31.

Berthiller, F., Crews, C., Dall'Asta, C., De Saeger, S., Haesaert, G., Karlovsky, P., … Stroka, J. (2013). Masked mycotoxins: A review. *Molecular Nutrition & Food Research*, *57*, 165–186.

Bhat, B., & Vasanthi, S. (2003). Mycotoxin food safety risk in developing countries: Food safety in food security and food trade. *International Food Policy Institute*, *10*(17), 1–3.

Biswas, S., Parvez, M. A. K., Shafiquzzaman, M., Nahar, S., & Rahman, M. N. (2010). Isolation and characterization of *Escherichia coli* in ready-to-eat foods vended in Islamic University, Kushtia. *Journal of BioScience*, *18*(1), 99–103.

Bohara, M. S. (2018). Microbiological safety of street vended foods in Mahendranagar, Farwestern Nepal. *International Journal of Food Safety, Nutrition, Public Health and Technology*, *10*(1), 1–9.

Bukar, A., Uba, A., & Oyeyi, T. I. (2009). Occurrence of some enteropathogenic bacteria in some minimally and fully processed ready-to-eat foods in Kano metropolis, Nigeria. *African Journal of Food Science*, *4*(2), 32–36.

Canini, N. D., Bala, J. J. O., Maraginot, E. N., & Mediana, B. C. B. (2013). Evaluation of street food vending in Ozamiz City. *Journal of Multidisciplinary Studies*, *1*(1), 104–124.

Cardinale, E., Abat, C., Bénédicte, C., Vincent, P., Michel, R., & Muriel, M. (2015). *Salmonella* and *Campylobacter* contamination of ready-to-eat street-vended pork meat dishes in Antananarivo, Madagascar: A risk for the consumers? *Foodborne Pathogens and Disease*, *12*(3), 197–202.

Cerna-Cortes, J. F., Leon-Montes, N., Cortes-Cueto, A. L., Salas-Rangel, L. P., Helguera-Repetto, A. C., Lopez-Hernandez, D., … Gonzalez-y-Merchand, J. A. (2015). Microbiological quality of ready-to-eat vegetables collected in Mexico city: Occurrence of aerobic-mesophilic Bacteria, fecal coliforms, and potentially pathogenic non-tuberculous *Mycobacteria*. *BioMed Research International*, *2015*, 789508.

Ceuppens, S., Boon, N., & Uyttendaele, M. (2013). Diversity of *Bacillus cereus* group strains is reflected in their broad range of pathogenicity and diverse ecological lifestyles. *FEMS Microbiology Ecology*, *84*(3), 433–450.

Ceuppens, S., Rajkovic, A., Heyndrickx, M., Tsilia, V., Van De Wiele, T., Boon, N., & Uyttendaele, M. (2011). Regulation of toxin production

by *Bacillus cereus* and its food safety implications. *Critical Reviews in Microbiology*, *37*(3), 188–213.

Ceyhun Sezgin, A., & Şanher, N. (2016). Street food consumption in terms of the food safety and health. *Journal of Human Sciences*, *13*(3), 4072–4083.

Chadha, M. S., Lole, K. S., Bora, M. H., & Arankalle, V. A. (2009). Outbreaks of hepatitis A among children in western India. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *103*(9), 911–916.

Chauhan, N., Uniyal, V., & Rawat, D. S. (2015). Microbial profiling of street foods of different locations at Dehradun city, India. *International Journal of Current Microbiology and Applied Sciences*, *4*(1), 340–347.

Cheesbrough, M. (1998). *Medical laboratory manual for tropical countries: Part 1* (1st ed.). Cambridge, UK: Cambridge University Press.

Chilaka, C. A., De Boevre, M., Atanda, O. O., & De Saeger, S. (2018). Prevalence of *Fusarium* mycotoxins in cassava and yam products from some selected Nigerian markets. *Food Control*, *84*, 226–231.

Chibeu, A. (2013). Bacteriophages in food safety. In A. Mendez-Vilas (Eds.), *Microbial pathogens and strategies for combating them: Science, technology and education* (pp. 1041–1052). Badajoz, Spain: Formatex Research Center.

Chin, C-S., Sorenson, J., Harris, J. B., Robins, W. P., Charles, R. C., Jean-Charles, R. R., … Waldor, M. K. (2011). The origin of the Haitian cholera outbreak strain. *New England Journal of Medicine*, *364*, 33–42.

Chukwu, E. E., Nwaokorie, F. O., Coker, A. O., Avila-Campos, M. J., Solis, R. L., Llanco, L. A., & Ogunsola, F. T. (2016). Detection of toxigenic *Clostridium perfringens* and *Clostridium botulinum* from food sold in Lagos, Nigeria. *Anaerobe*, *42*, 176–181.

Das, A., Nagananda, G. S., Bhattacharya, S., & Bhardwaj, S. (2010). Microbiological quality of street-vended Indian *chaats* sold in Bangalore. *Journal of Biological Sciences*, *10*, 255–260.

De Noordhout, C. M., Devleesschauwer, B., Angulo, F. J., Verbeke, G., Haagsma, J., Kirk, M., … Speybroeck, N. (2014). The global burden of listeriosis: A systematic review and meta-analysis. *The Lancet Infectious Diseases*, *14*(11), 1073–1082.

Derbew, G., Sahle, S., & Endris, M. (2013). Bacteriological assessment of some street vended foods in Gondar, Ethiopia. *Internet Journal of Food Safety*, *15*, 33–38.

Deshpande, S. S., Mohapatra, D., Tripathi, M. K., & Sadvatha, R. H. (2015). Kodo millet nutritional value and utilization in Indian foods. *Journal of Grain Processing and Storage*, *2*(2), 16–23.

Diaz, M., Wegmann, U., Akinyemi, N., Oguntoyinbo, F. A., Sayavedra, L., Mayer, M. J., & Narbad, A. (2018). Complete genome sequence of *Ochrobactrum haematophilum* FI11154, isolated from *kunu-zaki*, a Nigerian millet-based fermented food. *Genome Announcements*, *6*, e00428–18.

Divya, K. H., & Varadaraj, M. C. (2011). Prevalence of very low numbers of potential pathogenic isolates of *Yersinia enterocolitica* and *Yersinia intermedia* in traditional fast foods of India. *Indian Journal of Microbiology*, *51*(4), 461–468.

European Centre for Disease Prevention and Control (ECDC). (2013). Surveillance of communicable diseases in Europe - a concept to integrate molecular typing data into EU-level surveillance. *Version 2.4*. Stockholm, Sweden: Author. Retrieved from https://ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/surveillance-conceptmolecular%20typing-sept2011.pdf

Ediage, N. E., Mavungu, D. D. J., Monbaliu, S., Van Peteghem, C., & De Saeger, S. (2011). A validated multianalyte LC–MS/MS method for quantification of 25 mycotoxins in cassava flour, peanut cake and maize samples. *Journal of Agricultural and Food Chemistry*, *59*(10), 5173–5180.

El Bayomi, R. M., Ahmed, H. A., Awadallah, M. A. I., Mohsen, R. A., Abd El-Ghafar, A. E., & Abdelrahman, M. A. (2016). Occurrence, virulence factors, antimicrobial resistance, and genotyping of *Staphylococcus aureus* strains isolated from chicken products and humans. *Vector-Borne and Zoonotic Diseases*, *16*(3), 157–164.

Elbehiry, A., Marzouk, E., Hamada, M., Al-Dubai, M., Alyamani, E., Moussa, I. M., … Hemeg, H. A. (2017). Application of MALDI-TOF MS fingerprinting as a quick tool for identification and clustering of foodborne pathogens isolated from food products. *New Microbiologica*, *40*(4), 269–278.

Elfaki, A. E., & Elhakim, S. A. A. (2011). Quality evaluation of two Sudanese street foods of animal origin. *Advance Journal of Food Science and Technology*, *3*(3), 219–223.

El-Shenawy, M., El-Shenawy, M., Mañes, J., & Soriano, J. M. (2011). *Listeria* spp. in street vended ready-to-eat foods. *Interdisciplinary Perspectives on Infectious Diseases*, *2011*, 1–6.

Elzupir, A. O., Salih, A. O. A., Suliman, S. A., Adam, A. A., & Elhussein, A. M. (2011). Aflatoxins in peanut butter in Khartoum State, Sudan. *Mycotoxin Research*, *27*(3), 183–186. https://doi.org/10.1007/s12550-011-0094-7.

Eromo, T., Tassew, H., Daka, D., & Kibru, G. (2016). Bacteriological quality of street foods and antimicrobial resistance of isolates in Hawassa, Ethiopia. *Ethiopian Journal of Health Sciences*, *26*(6), 533–542.

European Food Safety Authority (EFSA). (2013). Scientific opinion on the evaluation of molecular typing methods for major food-borne microbiological hazards and their use for attribution modelling, outbreak investigation and scanning surveillance: Part 1 (evaluation of methods and applications). *EFSA Journal*, *11*(12), 3502.

Even, S., Leroy, S., & Charlier, C. (2010). Low occurrence of safety hazards in coagulase negative *Staphylococci* isolated from fermented foodstuffs. *International Journal of Food Microbiology*, *139*, 87–95.

Ezekiel, C. N., Abia, W. A., Ogara, I. M., Sulyok, M., Warth, B., & Krska, R. (2015). Fate of mycotoxins in two popular traditional cereal-based beverages (*kunu-zaki* and *pito*) from rural Nigeria. *LWT—Food Science and Technology*, *60*(1), 137–141.

Ezekiel, C. N., Anokwuru, C. P., Fari, A., Olorunfemi, M. F., Fadairo, O., Ekeh, H. A., … Akinsanmi, F. (2011). Microbiological quality and proximate composition of peanut cake (*Kulikuli*) in Nigerian markets. *Academia Arena*, *3*(4), 103–111.

Ezekiel, C. N., Ayeni, K. I., Ezeokoli, O. T., Sulyok, M., van Wyk, D. A. B., Oyedele, O. A., … Krska, R. (2019). High-throughput sequence analyses of bacterial communities and multi mycotoxin profiling during processing of different formulations of *kunu*, a traditional fermented beverage. *Frontiers in Microbiology*, *9*, 3282.

Ezekiel, C. N., Ayeni, K. I., Misihairabgwi, J. M., Somorin, Y. M., Chibuzor-Onyema, I. E., Oyedele, O. A., … Krska, R. (2018). Traditionally processed beverages in Africa: A review of the mycotoxin occurrence patterns and exposure assessment. *Comprehensive Reviews in Food Science and Food Safety*, *17*(2), 334–351.

Ezekiel, C. N., Kayode, F. O., Fapohunda, S. O., Olorunfemi, M. F., & Kponi, B. T. (2012). Aflatoxigenic moulds and aflatoxins in street-vended snacks in Lagos, Nigeria. *Internet Journal of Food Safety*, *14*, 83–88.

Ezekiel, C. N., Sulyok, M., Babalola, D. A., Warth, B., Ezekiel, V. C., & Krska, R. (2013). Incidence and consumer awareness of toxigenic *Aspergillus* section Flavi and aflatoxin $B_1$ in peanut cake from Nigeria. *Food Control*, *30*, 596–601.

Ezekiel, C. N., Sulyok, M., Ogara, I. M., Abia, W. A., Warth, B., Šarkanj, B., … Krska, R. (2019). Mycotoxins in uncooked and plate-ready household food from rural northern Nigeria. *Food and Chemical Toxicology*, *128*, 171–179.

Ezekiel, C. N., Sulyok, M., Warth, B., Odebode, A. C., & Krska, R. (2012). Natural occurrence of mycotoxins in peanut cake from Nigeria. *Food Control*, *27*, 338–342.

Fadahunsi, I. F., & Makinde, D. (2018). Occurrence, antibiotic susceptibility pattern and physiological studies of *pseudomonas* species isolated from ready to eat foods in Ibadan, Oyo state. *Journal of Applied Life Sciences International*, *18*(1), 1–9.

FAO & WHO (Food and Agriculture Organization & World Health Organization of the United Nations). (2004). Risk assessment of Listeria monocytogenes in ready-to-eat foods: Interpretative summary. Rome, Italy: FAO. Retrieved from https://apps.who.int/iris/handle/10665/42874

FAO & WHO (Food and Agriculture Organization & World Health Organization of the United Nations). (2018). The burden of foodborne diseases and the benefits of investing in safe food. Retrieved from https://www.who.int/food-safety/international-food-safety-conference/background-documents

FAO/WHO (Food and Agriculture Organization of the United Nations/World Health Organization). (2008). *Microbiological hazards in fresh leafy vegetables and herbs: Meeting report. Microbiological Risk Assessment Series No. 14*. Rome, Italy: FAO.

Feglo, P., & Sakyi, K. (2012). Bacterial contamination of street vending food in Kumasi, Ghana. *Journal of Medical and Biomedical Sciences*, *1*, 1–8.

Fellows, P., & Hilmi, M. (2011). Selling street and snack foods. *FAO Diversification Booklet 18. Rural Infrastructure and Agro-Industries Division*. Rome, Italy: FAO. Retrieved from https://fao.org/docrep/015

Filbert, M. E., & Brown, D. L. (2012). Aflatoxin contamination in Haitian and Kenyan peanut butter and two solutions for reducing such contamination. *Journal of Hunger & Environmental Nutrition*, *7*(2-3), 321–332.

Fowoyo, P. T., & Igbokwe, O. E. (2014). Impact of air pollution on the microbiological quality of ready to eat hawked foods sold around a cement factory in Lokoja, Nigeria. *American Journal of Research Communication*, *2*(11), 138–157.

Gdoura-Ben Amor, M., Siala, M., Zayani, M., Grosset, N., Smaoui, S., Messadi-Akrout, F., … Gdoura, R. (2018). Isolation, identification, prevalence, and genetic diversity of *Bacillus cereus* group bacteria from different foodstuffs in Tunisia. *Frontiers in Microbiology*, *9*, 447.

Gibb, H., Devleesschauwer, B., Bolger, P. M., Wu, F., Ezendam, J., Cliff, J., … Bellinger, D. (2015). World Health Organization estimates of the global and regional disease burden of four foodborne chemical toxins, 2010: A data synthesis. *F1000Research*, *4*, 1393.

Gitahi, M. G., Wangoh, J., & Njage, P. M. K. (2012). Microbial safety of street foods in industrial area, Nairobi. *Research Journal of Microbiology*, *7*(6), 297–308.

Grace, D. (2015). Food safety in low and middle income countries. *International Journal of Environmental Research and Public Health*, *12*, 10490–10507.

Grace, D. (2017). *Food safety in developing countries: Research gaps and opportunities. White paper*. Nairobi, Kenya: ILRI.

Guillet, C., Join-Lambert, O., Le Monnier, A., Leclercq, A., Mechaï, F., Mamzer-Bruneel, M.-F., … Lecuit, M. (2010). Human listeriosis caused by *Listeria ivanovii*. *Emerging Infectious Diseases*, *16*(1), 136–138.

Hafeez, Y., Iqbal, A., & Ahmad, M. (2012). Biotyping of *Bacillus cereus* from the street vended Foods in Srinagar area of Kashmir. *Veterinary World*, *5*(10), 590–593.

Hallin, M., Deplano, A., & Struelens, M. J. (2012). Molecular typing of bacterial pathogens: A tool for the epidemiological study and control of infectious diseases. In S. Morand, F. Beaudeau, & J. Cabaret (Eds.), *New frontiers of molecular epidemiology of infectious diseases* (pp. 9–25). Dordrecht, the Netherlands: Springer.

Hallowell, B. D., Parashar, U. D., & Hall, A. J. (2018). Epidemiologic challenges in norovirus vaccine development. *Human Vaccines & Immunotherapeutics*, *15*, 1279–1283. https://doi.org/10.1080/21645515.2018.1553594

Hassan, M. Z., Islam, M. S., Salauddin, M., Zafor, A. H. A., Scott, M. L., & Alam, S. (2016). Detection of enteric bacteria in the popular street food chotpoti in Dhaka, Bangladesh. *Asian Journal of Medical and Biological Research*, *2*(4), 596–602.

Havelaar, A. H., Kirk, M. D., Torgerson, P. R., Gibb, H. J., Hald, T., & Lake, R. J. … World Health Organization Foodborne Disease Burden Epidemiology Reference Group. (2015) World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLoS Medicine*, *12*(12), e1001923.

Hazen, T. H., Sahl, J. W., Fraser, C. M., Donnenberg, M. S., Scheutz, F., & Rasko, D. A. (2013). Refining the pathovar paradigm *via* phylogenomics of the attaching and effacing *Escherichia coli*. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 12810–12815.

Hendriksen, R. S., Price, L. B., Schupp, J. M., Gillece, J. D., Kaas, R. S., Engelthaler, D. M., … Arestrup, F. M. (2011). Population genetics of *Vibrio cholerae* from Nepal in 2010: Evidence on the origin of the Haitian Outbreak. *mBio*, *2*(4), e00157–11.

Hennekinne, J. A., De Buyser, M. L., & Dragacci, S. (2012). *Staphylococcus aureus* and its food poisoning toxins: Characterization and outbreak investigation. *FEMS Microbiology Reviews*, *36*, 815–836.

Hewitt, J., & Greening, G. E. (2004). Survival and persistence of norovirus, hepatitis A virus, and feline calicivirus in marinated Mussels. *Journal of Food Protection*, *67*(8), 1743–1750.

Hu, D. L., Zhu, G., Mori, F., Omoe, K., Okada, M., Wakabayashi, K., … Nakane, A. (2007). Staphylococcal enterotoxin induces emesis through increasing serotonin release in intestine and it is down regulated by cannabinoid receptor 1. *Cell Microbiology*, *9*, 2267–2277.

Huong, B. T. M., Mahmud, Z. H., Neogi, S. B., Kassu, A., Van Nhien, N., Mohammad, A., … Khan, N. C. (2009). Toxigenicity and genetic diversity of *Staphylococcus aureus* isolated from Vietnamese ready-to-eat foods. *Food Control*, *21*, 166–171.

Huys, A., Grau, K. R., & Karst, S. M. (2020). Development of oral rotavirus and norovirus vaccines. In P. A. Kozlowski (Eds.), *Mucosal vaccines* (2nd ed., pp. 699–712). Dordrecht, the Netherlands: Springer.

International Agency for Research on Cancer (IARC). (1993). Some naturally occurring substances: Food items and constituents, heterocyclic amines and mycotoxins. *IARC Monographs on Evaluation of Carcinogenic Risk to Humans*. Lyon, France: Author.

International Agency for Research on Cancer (IARC). (2015). *Mycotoxin control in low- and middle-income countries* (IARC Working Group Report No. 9). Lyon, France: Author.

Igbinosa, E. O., Rathje, J., Habermann, D., Brinks, E., Cho, G-S., & Franz, C. A. M. P. (2018). Draft genome sequence of multidrug-resistant strain *Citrobacter portucalensis* MBTC-1222, isolated from *uziza* (*Piper guineense*) leaves in Nigeria. *Genome Announcements*, *6*, e00123–18.

Iwuoha, C. I., & Eke, O. S. (1996). Nigerian indigenous fermented foods: Their traditional process operation, inherent problems, improvements and current status. *Food Research International*, *29*(5-6), 527–540.

Jabbar, M. A., Baker, D., & Fadiga, M. L. (2010). *Demand for livestock products in developing countries with a focus on quality and safety attributes: Evidence from Asia and Africa* (ILRI Research Report 24). Nairobi, Kenya: ILRI.

Jaffee, S., Henson, S., Unnevehr, L., Grace, D., & Cassou, E. (2019). *The safe food imperative: Accelerating progress in low-and middle-income countries. Agriculture and food series*. Washington, DC: World Bank.

Jalbani, N., & Soylak, M. (2015). Separation- preconcentration of nickel and lead in food samples by a combination of solid-liquid-solid dispersive extraction using SiO2 nanoparticles, ionic liquid based dispersive liquid-liquid micro-extraction. *Talanta*, *131*, 361–365.

Joint FAO/WHO Expert Committee on Food Additives (JECFA). (2017). *Evaluation of certain contaminants in food. Eighty-third report of the Joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series 1002: WHO and FAO 2017*. Geneva, Switzerland: WHO.

Joint FAO/WHO Expert Committee on Food Additives (JECFA). (2018). *WHO food additives series: 74 FAO JECFA Monographs 19 bis*. Geneva, Switzerland: WHO.

Johnson, E. A., & Montecucco, C. (2018). Chapter 11: Botulism. In A. W. G. Engel (Eds.), *Neuromuscular junction disorders* (Vol. *91*, pp. 333–368). Handbook of clinical neurology. Amsterdam, the Netherlands: Elsevier.

Jonathan, S. G., Adeniyi, M. A., & Asemoloye, M. D. (2015). Fungal biodeterioration, aflatoxin contamination and nutrient value of '*aadun*'. *Researcher*, *7*(12), 26–32.

Jonathan, S. G., Okoawo, E. E., & Asemoloye, M. D. (2016). Fungi and aflatoxin contamination of sausage rolls in Ibadan Nigeria. *International Journal of Scientific Research in Knowledge*, *4*(5), 99–104.

Kadariya, J., Smith, T. C., & Thapaliya, D. (2014). *Staphylococcus aureus* and Staphylococcal food-borne disease: An ongoing challenge in public health. *BioMed Research International*, *2014*, 827965.

Kamala, A., Ortiz, J., Kimanya, M., Haesaert, G., Donoso, S., Tiisekwa, B., & De Meulenaer, B. (2015). Multiple mycotoxin co-occurrence in maize grown in three agro-ecological zones of Tanzania. *Food Control*, *54*, 208–215.

Kamala, A., Shirima, C., Jani, B., Bakari, M., Sillo, H., Rusibamayila, N., … the investigation team. (2018). Outbreak of an acute aflatoxicosis in Tanzania during 2016. *World Mycotoxin Journal*, *11*, 311–320.

Karlovsky, P., Suman, M., Berthiller, F., De Meester, J., Eisenbrand, G., Perrin, I., … Dussort, P. (2016). Impact of food processing and detoxification treatments on mycotoxin contamination. *Mycotoxin Research*, *32*(4), 179–205.

Khadka, S., Adhikari, S., Rai, T., Ghimire, U., & Parajuli, A. (2018). Bacterial contamination and risk factors associated with street-vended *panipuri* sold in Bharatpur, Nepal. *International Journal of Food Research*, *5*, 32–38.

Khairuzzaman, M., Chowdhury, F. M., Zaman, S., Al Mamun, A., & Bari, M. L. (2014). Food safety challenges towards safe, healthy, and nutritious street foods in Bangladesh. *International Journal of Food Science*, *2014*, 1–9.

Kharel, N., Palni, U., & Tamang, J. P. (2016). Microbiological assessment of ethnic street foods of the Himalayas. *Journal of Ethnic Foods*, *3*(3), 235–241.

Kiranmai, B., Siva Kamesh, A., Divija, H., & Sara, P. S. (2016). A cross-sectional study on microbiological quality of street food in Hyderabad, Telangana, India. *International Journal of Health Sciences & Research*, *6*(10), 23–27.

Kirk, M. D., Pires, S. M., Black, R. E., Caipo, M., Crump, J. A., Devleesschauwer, B., … Angulo, F. J. (2015a). World Health Organization estimates of the global and regional disease burden of 22 foodborne bacterial, protozoal, and viral diseases, 2010: A data synthesis. *PLoS Medicine*, *12*(12), e1001921.

Kirk, M. D., Pires, S. M., Black, R. E., Caipo, M., Crump, J. A., Devleesschauwer, B., … Angulo, F. J. (2015b). Correction: World Health Organization estimates of the global and regional disease burden of 22 foodborne bacterial, protozoal, and viral diseases, 2010: A Data Synthesis. *PLoS Medicine*, *12*(12), e1001940.

Koopmans, M., & Duizer, E. (2004). Foodborne viruses: An emerging problem. *International Journal of Food Microbiology*, *90*(1), 23–41.

Kouassi, K. A., Dadie, A. T., Nanga, Z. Y., Dje, K. M., & Loukou, Y. G. (2011). Prevalence of sulphite reducing *Clostridium* species in barbecued meat in Abidjan, Côte d'Ivoire. *Journal of Applied Biosciences*, *38*, 2518–2522.

Kraig, B., & Taylor, C. (2013). *Street food around the world: An encyclopaedia of food and culture*. Santa Barbara, CA: ABC-CLIO.

Kumar, A., Basu, S., Vashishtha, V., & Choudhury, P. (2016). Burden of rotavirus diarrhea in under-five Indian children. *Indian Pediatrics*, *53*(7), 607–617.

Kumar, A., Parappurathu, S., & Jee, S. (2013). Do dairy co-operatives enhance milk production, productivity and quality? Evidences from the Indo-Gangetic Plain of India. *Indian Journal of Agricultural Economics*, *68*(3), 457–468.

Kunadu, A. P., Ofosu, D. B., Aboagye, E., & Tano-Debrah, K. (2016). Food safety knowledge, attitudes and self-reported practices of food handlers in institutional foodservice in Accra, Ghana. *Food Control*, *69*, 324–330.

Lamhoujeb, S., Fliss, I., Ngazoa, S. E., & Jean, J. (2009). Molecular study of the persistence of infectious human norovirus on food-contact surfaces. *Food and Environmental Virology*, *1*(2), 51–56.

Law, J. W-F., Ab Mutalib, N-S., Chan, K.-G., & Lee, L-H. (2015). Rapid methods for the detection of foodborne bacterial pathogens: Principles, applications, advantages and limitations. *Frontiers in Microbiology*, *5*, 770.

Lee, N., Kwon, K. Y., Oh, S. K., Chang, H. J., Chun, H. S., & Choi, S. W. (2015). A multiplex PCR assay for simultaneous detection of *Escherichia coli O157:H7*, *Bacillus cereus, Vibrio parahaemolyticus, Salmonella* spp., *Listeria monocytogenes*, and *Staphylococcus aureus* in Korea ready-to-eat food. *Foodborne Pathogens and Disease*, *11*, 574–580.

Leekitcharoenphon, P., Nielsen, E. M., Kaas, R. S., Lund, O., & Aarestrup, F. M. (2014). Evaluation of whole genome sequencing for outbreak detection of *Salmonella enterica*. *PLoS ONE*, *9*(2), e87991.

Lindh, J. M., & Lehane, M. J. (2011). The tsetse fly *Glossina fuscipes fuscipes* (Diptera: Glossina) harbours a surprising diversity of bacteria other than symbionts. *Antonie van Leeuwenhoek*, *99*(3), 711–720.

Lopman, B. A., Steele, D., Kirkwood, C. D., & Parashar, U. D. (2016). The vast and varied global burden of norovirus: Prospects for prevention and control. *PLoS Medicine*, *13*(4), e1001999.

Madueke, S. N., Awe, S., & Jonah, A. I. (2014). Microbiological analysis of street foods along Lokoja-Abuja Express Way, Lokoja. *American Journal of Research Communication*, *2*(1), 196–211.

Majeed, M., Khaneghah, A. M., Kadmic, Y., Khanf, M. U., & Shariatig, M. A. (2017). Assessment of ochratoxin A in commercial corn and wheat products. *Current Nutrition & Food Science*, *13*, 1–5.

Majeed, S., Iqbal, M., Asi, M. R., & Iqbal, S. Z. (2013). Aflatoxins and ochratoxin A contamination in rice, corn and corn products from Punjab, Pakistan. *Journal of Cereal Science*, *58*(3), 446–450.

Makelele, L. K., Kazadi, Z. A., Oleko, R. W., Foma, R., Mpalang, R. K. A., Ngbolua, K-T-N., & Gédeon, B. N. (2015). Microbiological quality of food sold by street vendors in Kisangani, Democratic Republic of Congo. *African Journal of Food Science*, *9*(5), 285–290.

Makun, H. A., Adeniran, A. L., Mailafiya, S. C., Ayanda, I. S., Mudashiru, A. T., Ojukwu, U. J., … Sahilu, D. A. (2013). Natural occurrence of ochratoxin A in some marketed Nigerian foods. *Food Control*, *31*, 566–571.

Malachova, A., Sulyok, M., Beltran, E., Berthiller, F., & Krska, R. (2014). Optimization and validation of a quantitative liquid chromatography-tandem mass spectrometric method covering 295 bacterial and fungal metabolites including all regulated mycotoxins in four model food matrices. *Journal of Chromatography A*, *1362*, 145–156.

Mandal, P. K., Biswas, A. K., Choi, K., & Pal, U. K. (2011). Methods for rapid detection of foodborne pathogens: An overview. *American Journal of Food Technology*, *6*, 87–102.

Manguiat, L. S., & Fang, T. J. (2013). Evaluation of DAS™ kits for the detection of food-borne pathogens in chicken- and meat-based street-vended foods. *Journal of Food and Drug Analysis*, *21*(2), 198–205.

Mans, J. (2019). Norovirus infections and disease in lower-middle-and low-income countries, 1997–2018. *Viruses*, *11*, 341.

Manukumar, H. M., & Umesha, S. (2017). MALDI-TOF-MS based identification and molecular characterization of food associated methicillin-resistant *Staphylococcus aureus*. *Scientific Reports*, *7*(1), 11414.

Manyi, M. M., Idu, O. F., & Ogbonna, I. O. (2014). Microbiological and parasitic quality of *suya* (roasted beef) sold in Makurdi, Benue state, Nigeria. *African Journal of Microbiology Research*, *8*(35), 3235–3242.

Mattison, K., Sebunya, T. K., Shukla, A., Noliwe, L. N., & Bidawid, S. (2010). Molecular detection and characterization of noroviruses from children in Botswana. *Journal of Medical Virology*, *82*(2), 321–324.

Matumba, L., Monjerezi, M., Biswick, T., Mwatseteza, J., Makumba, W., Kamangira, D., & Mtukuso, A. (2014). A survey of the Incidence and level of aflatoxin contamination in a range of locally and imported processed foods on Malawian retail market. *Food Control*, *39*, 87–91.

Maunula, L., & von Bonsdorff, C.-H. (2016). Foodborne viruses in ready-to-eat foods. In P. Kotzekidou (Eds.), *Food hygiene and toxicology in ready-to-eat foods* (pp. 51–68). Amsterdam, the Netherlands: Elsevier.

Mensah, P., Yeboah-Manu, D., Owusu-Darko, K., & Ablordey, A. (2002). Street foods in Accra, Ghana: How safe are they? *Bulletin of the World Health Organization*, *80*, 546–554.

Misihairabgwi, J. M., Ezekiel, C. N., Sulyok, M., Shephard, G. S., & Krska, R. (2019). Mycotoxin contamination of foods in Southern Africa: A 10-year review (2007–2016). *Critical Reviews in Food Science and Nutrition*, *59*(1), 43–58. https://doi.org/10.1080/10408398.2017.1357003

Motayo, B. O., Faneye, A. O., & Adeniji, J. A. (2018). Epidemiology of rotavirus A in Nigeria: Molecular diversity and current Insights. *Journal of Pathogens*, *2018*, 1–7.

Mrityunjoy, A., Kaniz, F., Fahmida, J., Shanzida, J. S., Md. Aftab, U., & Rashed, N. (2013). Prevalence of *Vibrio cholerae* in different food samples in the city of Dhaka, Bangladesh. *International Food Research Journal*, *20*(2), 1017–1022.

Mukherjee, A., Chattopadhyay, S., Bagchi, P., Dutta, D., Singh, N. B., Arora, R., … Chawla-Sarkar, M. (2010). Surveillance and molecular characterization of rotavirus strains circulating in Manipur, North-Eastern India: Increasing prevalence of emerging G12 strains. *Infection, Genetics and Evolution*, *10*(2), 311–320.

Mupunga, I., Lebelo, S. L., Mngqawa, P., Rheeder, J. P., & Katerere, D. R. (2014). Natural occurrence of aflatoxins in peanuts and peanut butter from Bulawayo, Zimbabwe. *Journal of Food Protection*, *77*, 1814–1818.

Mushtaq, M., Sultana, B., Anwar, F., Khan, M. Z., & Ashrafuzzaman, M. (2012). Occurrence of aflatoxins in selected processed foods from Pakistan. *International Journal of Molecular Sciences*, *13*, 8324–8337.

Muyanja, C., Nayiga, L., Brenda, N., & Nasinyama, G. (2011). Practices, knowledge and risk factors of street food vendors in Uganda. *Food Control*, *22*(10), 1551–1558.

Mwangi, A. M., den Hartog, A. P., Mwadime, R. K. N., van Staveren, W. A., & Foeken, D. W. J. (2002). Do street food vendors sell a sufficient variety of foods for a healthful diet? The case of Nairobi. *Food and Nutrition Bulletin*, *23*(1), 48–56.

Nair, R., Ghadevaru, S., Manimehali, N., & Athmaselvi, K. A. (2015). Survey of mycotoxin levels in ready-to-eat fruit jam. *Journal of Ready to Eat Food*, *2*(1), 1–5.

Neufingerl, N., Djuwita, R., Otten-Hofman, A., Nurdiani, R., Garczarek, U., Muhardi, L., … Eilander, A. (2016). Generating fatty acid and vitamin D composition data of Indonesian foods. *Journal of Food Composition and Analysis*, *50*, 36–48.

Newell, D. G., Koopmans, M., Verhoef, L., Duizer, E., Aidara-Kane, A., Sprong, H., … Kruse, H. (2010). Food-borne diseases—The challenges of 20 years ago still persist while new ones continue to emerge. *International Journal of Food Microbiology*, *139*, S3–S15.

Niyonzima, E., Ongol, M. P., Brostaux, Y., Korsak Koulagenko, N., Daube, G., Kimonyo, A., & Sindic, M. (2017). Consumption patterns, bacteriological quality and risk factors for *Salmonella* contamination in meat-based meals consumed outside the home in Kigali, Rwanda. *Food Control*, *73*, 546–554.

Nkere, C. K., Ibe, N. I., & Iroegbu, C. U. (2011). Bacteriological quality of foods and water sold by vendors and in restaurants in Nsukka, Enugu State, Nigeria: A comparative study of three microbiological methods. *Journal of Health, Population, and Nutrition*, *29*(6), 560–566.

Nonga, H. E., Ngowi, H. A., Mdegela, R. H., Mutakyawa, E., Nyahinga, G. B., William, R., & Mwadini, M. M. (2015). Survey of physicochemical characteristics and microbial contamination in selected

food locally vended in Morogoro Municipality, Tanzania. *BMC Research Notes*, *8*(1), 727.

Nyenje, M. E., Green, E., & Ndip, R. N. (2012). Biofilm formation and adherence characteristics of *Listeria ivanovii* strains isolated from ready-to-eat foods in Alice, South Africa. *The Scientific World Journal*, *2012*, 1–7.

Nyirahakizimana, H., Mwamburi, L., Wakhisi, J., Mutegi, C. K., Christie, M. E., & Wagacha, J. M. (2013). Occurrence of *Aspergillus* species and aflatoxin contamination in raw and roasted peanuts from formal and informal markets in Eldoret and Kericho towns, Kenya. *Advances in Microbiology*, *3*, 333–342.

Obadina, A. O., Oyewole, O. B., & Ajisegiri, O. A. (2013). Identification of hazards and critical control point (ccp) for "*suya*" processing in South-West Nigeria. *Journal of Food Processing and Preservation*, *38*(5), 2057–2060.

Obande, G., Umeh, E., Azua, E., Chuku, A., & Adikwu, P. (2018). Incidence and antibiotic susceptibility pattern of *Escherichia coli* and *Staphylococcus aureus* isolated from meat pie sold in a Nigerian North Central town. *Janaki Medical College Journal of Medical Science*, *6*(1), 21–28.

Okeke, C. A., Ezekiel, C. N., Nwangburuka, C. C., Sulyok, M., Ezeamagu, C. O., Adeleke, R. A., … Krska, R. (2015). Bacterial diversity and mycotoxin reduction during maize fermentation (steeping) for *ogi* production. *Frontiers in Microbiology*, *6*, 1402.

Okeke, C. A., Ezekiel, C. N., Sulyok, M., Ogunremi, O. R., Ezeamagu, C. O., Šarkanj, B., … Krska, R. (2018). Traditional processing impacts mycotoxin levels and nutritional value of ogi—A maize-based complementary food. *Food Control*, *86*, 224–233.

Omemu, A. M., & Aderoju, S. T. (2008). Food safety knowledge and practices of street food vendors in the city of Abeokuta, Nigeria. *Food Control*, *19*(4), 396–402.

Omore, R., Khagayi, S., Ogwel, B., Onkoba, R., Ochieng, J. B., Juma, J., … Tate, J. E. (2019). Rates of hospitalization and death for all-cause and rotavirus acute gastroenteritis before rotavirus vaccine introduction in Kenya, 2010–2013. *BMC Infectious Diseases*, *19*(1), 47.

Onifade, D. A., Adesokan, I. A., & Adebayo-Tayo, B. C. (2014). Mycoflora and aflatoxin contamination of *kokoro* -a Nigerian maize snack. *The Asia Journal of Applied Microbiology*, *1*(1), 1–5.

Oranusi, U. S., & Braide, W. (2012). A study of microbial safety of ready-to-eat foods vended on highways: Onitsha-Owerri, south east Nigeria. *International Research Journal of Microbiology*, *3*(2), 66–71.

Oranusi, S., & Nubi, F. E. (2016). Microbiological safety evaluation of ready to eat shrimps and snails sold along Lagos–Shagamu expressway, Nigeria. *Covenant Journal of Physical and Life Science*, *4*(1), 20–32.

Oyedele, O. A., Ezekiel, C. N., Sulyok, M., Adetunji, M. C., Warth, B., Atanda, O. O., & Krska, R. (2017). Mycotoxin risk assessment for consumers of groundnut in domestic markets in Nigeria. *International Journal of Food Microbiology*, *251*, 24–32.

Parashar, U. D., Burton, A., Lanata, C., Boschi-Pinto, C., Shibuya, K., Steele, D., … Glass, R. I. (2009). Global mortality associated with rotavirus disease among children in 2004. *The Journal of Infectious Diseases*, *200*(s1), S9–S15.

Patel, M. M., Glass, R., Desai, R., Tate, J. E., & Parashar, U. D. (2012). Fulfilling the promise of rotavirus vaccines: How far have we come since licensure? *Lancet Infectious Disease*, *12*, 561–570.

Pereira, V. L., Fernandes, J. O., & Cunha, S. C. (2014). Mycotoxins in cereals and related foodstuffs: A review on occurrence and recent methods of analysis. *Trends in Food Science & Technology*, *36*(2), 96–136.

Pinchuk, I. V., Beswick, E. J., & Reyes, V. E. (2010). Staphylococcal enterotoxins. *Toxins*, *2*, 2177–2197.

Popoff, M. R. (2013). Botulinum neurotoxins: More and more diverse and fascinating toxic proteins. *Journal of Infectious Diseases*, *209*(2), 168–169.

Privitera, D., & Nesci, F. S. (2015). Globalization vs. local. The role of street food in the urban food system. 2nd International Conference 'Economic Scientific Research - Theoretical, Empirical and Practical Approaches', ESPERA 2014, 13–14 November 2014, Bucharest, Romania. *Procedia Economics and Finance*, *22*, 716–722.

Probst, C., Bandyopadhyay, R., & Cotty, P. J. (2014). Diversity of aflatoxin-producing fungi and their impact on food safety in sub-Saharan Africa. *International Journal of Food Microbiology*, *174*, 113–122.

Proietti, I., Frazzoli, C., & Mantovani, A. (2014). Identification and management of toxicological hazards of street foods in developing countries. *Food and Chemical Toxicology*, *63*, 143–152.

Rajkovic, A., Uyttendaele, M., & Debevere, J. (2005). Impact of non typical food matrice and cell density on *Bacillus cereus* emetic toxin production. *Communications in Agricultural and Applied Biological Science*, *70*, 11–13.

Randazzo, C. L., Scifo, G. O., Tomaselli, F., & Caggia, C. (2009). Polyphasic characterization of bacterial community in fresh cut salads. *International Journal of Food Microbiology*, *128*(3), 484–490.

Rane, S. (2011). Street vended food in developing world: Hazard analyses. *Indian Journal of Microbiology*, *51*, 100–106.

Ray, M., Ghosh, K., Singh, S., & Chandra Mondal, K. (2016). Folk to functional: An explorative overview of rice-based fermented foods and beverages in India. *Journal of Ethnic Foods*, *3*(1), 5–18.

Reda, N., Ketema, B., & Tsige, K. (2017). Microbiological quality and safety of some-street vended foods in Jimma Town, Southwestern Ethiopia. *African Journal of Microbiology Research*, *11*(14), 574–585.

Rheinländer, T., Olsen, M., Bakang, J. A., Takyi, H., Konradsen, F., & Samuelsen, H. (2008). Keeping up appearances: Perceptions of street food safety in urban Kumasi, Ghana. *Journal of Urban Health*, *85*(6), 952–964.

Riddle, M. S., Chen, W. H., Kirkwood, C. D., & MacLennan, C. A. (2018). Update on vaccines for enteric pathogens. *Clinical Microbiology and Infection*, *24*, 1039–1045.

Ritchie, H., & Roser, M. (2019). *Water use and sanitation*. Retrieved from https://ourworldindata.org/water-use-sanitation

Samson, R. A., Houbraken, J., Thrane, U., Frisvad, J. C., & Anderson, B. (2019). *Food and indoor fungi* (2nd ed.). Utrecht, the Netherlands: Westerdijk Laboratory Series, Westerdijk Fungal Biodiversity Institute.

Sanches-Pereira, A., Onguglo, B., Pacini, H., Gómez, M. F., Coelho, S. T., & Muwanga, M. K. (2017). Fostering local sustainable development in Tanzania by enhancing linkages between tourism and small-scale agriculture. *Journal of Cleaner Production*, *162*, 1567–1581.

Schelin, J., Wallin-Carlquist, N., Cohn, M. T., Lindqvist, R., Barker, G. C., & Rådström, P. (2011). The formation of *Staphylococcus aureus* enterotoxin in food environments and advances in risk assessment. *Virulence*, *2*, 580–592.

Schwartz, L. M., Zaman, K., Yunus, M., Basunia, A. H., Faruque, A. S. G., Ahmed, T., … Victor, J. C. (2019). Impact of rotavirus vaccine introduction in children less than 2 years of age presenting for medical care with diarrhea in rural Matlab, Bangladesh. *Clinical Infectious Diseases*, *69*(12), 2059–2070. https://doi.org/10.1093/cid/ciz133

Seitz, P., & Blokesch, M. (2013). Cues and regulatory pathways involved in natural competence and transformation in pathogenic and environmental Gram-negative bacteria. *FEMS Microbiology Reviews*, *37*(3), 336–363.

Setyabudi, F. M. C. S., Nuryono, N., Wedhastri, S., Mayerm, H. K., & Razzazi-Fazeli, E. (2012). Limited survey of deoxynivalenol occurrence in maize kernels and maize- products collected from Indonesian retail market. *Food Control*, *24*, 121–127.

Shah, M. P., Tate, J. E., Mwenda, J. M., Steele, A. D., & Parashar, U. D. (2017). Estimated reductions in hospitalizations and deaths from childhood diarrhea following implementation of rotavirus vaccination in Africa. *Expert Review of Vaccines*, *16*(10), 987–995.

Sharma, S., Gupta, D., & Sharma, Y. P. (2013). Aflatoxin contamination in chilgoza pine nuts (*Pinus gerardiana Wall.*) commercially available in retail markets of Jammu, India. *International Journal of Pharma and Biosciences*, *4*(2), 751–759.

Shiota, M., Saitou, K., Mizumoto, H., Matsusaka, M., Agata, N., Nakayama, M., … Hata, D. (2010). Rapid detoxification of cereulide in *Bacillus cereus* food poisoning. *Pediatrics*, *125*(4), e951–e955.

Sindhu, K. N. C., Babji, S., & Ganesan, S. K. (2017). Impact of rotavirus vaccines in low and middle-income countries. *Current Opinion in Infectious Diseases*, *30*(5), 473–481.

Skretteberg, L. G., Lyran, B., Holen, B., Jansson, A., Fohgelberg, P., Siivinen, K., … Jensen, B. H. (2015). Pesticide residues in food of plant origin from Southeast Asia—A Nordic project. *Food Control*, *51*, 225–235.

Smith, J. L., & Fratamico, P. M. (2005). Emerging foodborne pathogens. In P. M. Fratamico, A. K. Bhunia, & J. L. Smith (Eds.), *Foodborne pathogens: Microbiology and molecular biology* (454pp.). Norwich: Caister Academic.

Smith, S., Opere, B., Fowora, M., Aderohunmu, A., Ibrahim, R., Omonigbehin, E., … Adeneye, A. (2012). Molecular characterization of *Salmonella* spp. directly from snack and food commonly sold in Lagos, Nigeria. *Southeast Asian Journal of Tropical Medicine and Public Health*, *43*(3), 718–723.

Sombie, J. I. N., Ezekiel, C. N., Sulyok, M., Ayeni, K. I., Jonsyn-Ellis, F., & Krska, R. (2018). Survey of roasted street-vended nuts in Sierra Leone for toxic metabolites of fungal origin. *Food Additives & Contaminants: Part A*, *35*(8), 1573–1580.

Somda, N. S., Bonkoungou, Q. J. I., Zongo, C., Kagambèga, A., Bassolé, I. H. N., Traoré, Y., … Savadogo, A. (2018). Safety of ready-to- eat chicken in Burkina Faso: Microbiological quality, antibiotic resistance, and virulence genes in *Escherichia coli* isolated from chicken samples of Ouagadougou. *Food Science & Nutrition*, *2018*, 1–8.

Stals, A., Baert, L., Van Coillie, E., & Uyttendaele, M. (2012). Extraction of food-borne viruses from food samples: A review. *International Journal of Food Microbiology*, *153*(1–2), 1–9.

Stecchini, M. L., Del Torre, M., & Polese, P. (2013). Survival strategies of *Bacillus* spores in food. *Indian Journal of Experimental Biology*, *51*(11), 905–909.

Swaminathan, B., & Gerner-Smidt, P. (2007). The epidemiology of human listeriosis. *Microbes and Infection*, *9*(10), 1236–1243.

Tabashsum, Z., Khalil, I., Nazimuddin, M., Mollah, A. K. M. M., Inatsu, Y., & Bari, M. L. (2013). Prevalence of foodborne pathogens and spoilage microorganisms and their drug resistant status in different street foods of Dhaka city. *Agriculture Food and Analytical Bacteriology*, *3*(4), 281–292.

Tambekar, D. H., Jaiswal, V. J., Dhanorkar, D. V., Gulhane, P. B., & Dudhane, M. N. (2009). Microbial quality and safety of street vended fruit juices: A case study of Amravati city. *Internet Journal of Food Safety*, *10*, 72–76.

Taneja, D. K., & Malik, A. (2012). Burden of rotavirus in India—Is rotavirus vaccine an answer to it? *Indian Journal of Public Health*, *56*, 17–21.

Tardieux, I., & Menard, R. (2008). Migration of apicomplexa across biological barriers: The toxoplasma and plasmodium rides. *Traffic*, *9*, 627–635.

Teshale, E. H., Howard, C. M., Grytdal, S. P., Handzel, T. R., Barry, V., Kamili, S., … Hu, D. J. (2010). Hepatitis E epidemic, Uganda. *Emerging Infectious Diseases*, *16*(1), 126–129.

Ubwa, S. T., Abah, J., Atu, B. O., Tyohemba, R. L., & Yande, J. T. (2014). Assessment of total aflatoxins level of two major nuts consumed in Makurdi Benue State, Nigeria. *International Journal of Nutrition and Food Sciences*, *3*(5), 397–403.

Van Belkum, A., Tassios, P. T., Dijkshoorn, L., Haeggman, S., Cookson, B., Fry, N. K., … Struelens, M. (2007). Guidelines for the validation and application of typing methods for use in bacterial epidemiology. *Clinical Microbiology and Infection*, *13*, 1–46.

Von Holy, A., & Makhoane, F. M. (2006). Improving street food vending in South Africa: Achievements and lessons learned. *International Journal of Food Microbiology*, *111*(2), 89–92.

Warth, B., Parich, A., Atehnkeng, J., Bandyopadhyay, R., Schuhmacher, R., Sulyok, M., & Krska, R. (2012). Quantitation of mycotoxins in food and feed from Burkina Faso and Mozambique using a modern LC-MS/MS multitoxin method. *Journal of Agricultural and Food Chemistry*, *60*(36), 9352–9363.

WHO (World Health Organization). (2017). *Drinking water*. Retrieved from www.who.int/newsroom/fact-sheets/detail/drinking-water

Wild, C. P., & Gong, Y. Y. (2010). Mycotoxins and human disease: A largely ignored global health issue. *Carcinogenesis*, *31*(1), 71–82.

World Bank (2019). World Bank country and lending groups. Retrieved from https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

World Health Organization (WHO). (2010). Basic steps to improve safety of street-vended food. *International Food Safety Authorities Network (INFOSAN) Information Note No. 3/2010-Safety of street-vended food*. Retrieved from http://www.who.int/foodsafety/fs_management/No_03_StreetFood_Jun10_en.pdf

Yannick, N., Rawlings, N., & Emmanuela, A. (2013). Assessment of bacteriological quality of cooked pork meat sold along the commercial streets of Nkwen through Bambili Metropolis, Cameroon. *African Journal of Food Science*, *7*(12), 441–445.

Yeboah-Manu, D., Kpeli, G., Akyeh, M., & Bimi, L. (2010). Bacteriological quality of ready-to-eat foods sold on and around University of Ghana campus. *Research Journal of Microbiology*, *5*, 130–136.

Yongsi, N. H. B. (2018). Eating to live or eating to damage one's health: Microbiological risks associated with street-vended foods in a subtropical urban setting (Yaoundé-Cameroon). *Nutrition & Food Science*, *6*(4), 001–0013.

Zaghloul, R. A., El-Shenawy, M. A., Neweigy, N. A., Abou-Aly, H. E., El-dairouty, R. K., El-Kholy, W. I., … Micó, L. (2014). *Listeria* spp. and Enterobacteriaceae group in sandwiches of meat and meat products. *British Microbiology Research Journal*, *4*(4), 360–368.

Zell, C., Resch, M., Rosenstein, R., Albrecht, T., Hertel, C., & Gotz, F. (2008). Characterization of toxin production of coagulase negative *Staphylococci* isolated from food and starter cultures. *International Journal of Food Microbiology*, *49*, 1577–1593.

Zhao, X., Lin, C. W., Wang, J., & Oh, D. H. (2014). Advances in rapid detection methods for foodborne pathogens. *Journal of Microbiology and Biotechnology*, *24*, 297–312.

**How to cite this article:** Makinde OM, Ayeni KI, Sulyok M, Krska R, Adeleke RA, Ezekiel CN. Microbiological safety of ready-to-eat foods in low- and middle-income countries: A comprehensive 10-year (2009 to 2018) review. *Compr Rev Food Sci Food Saf*. 2020;19:703–732. https://doi.org/10.1111/1541-4337.12533