FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

EatSafe - Evidence and Action Towards Safe, Nutritious Food

Occurrence of Foodborne Disease Hazards in Foods and Beverages Consumed in Nigeria: A Systematic Literature Review

September 2020

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This EatSafe report presents evidence that will help engage and empower consumers and market actors to better obtain safe nutritious food. It will be used to design and test consumer-centered food safety interventions in informal markets through the EatSafe program.

Recommended Citation: Global Alliance for Improved Nutrition. 2020. Occurrence of foodborne disease hazards in foods and beverages consumed in Nigeria: A Systematic Literature Review. A USAID EatSafe Project Report.

Acknowledgements: This review was undertaken, and the report written, by Delia Randolph, with input and feedback provided by Florence Mutua, Lian Thomas, Elisabetta Lambertini and Stella Nordhagen. The following ILRI team supported the review process: Emma Kwoba, David Oduori, Lina Mego, Filipe Miguel, Irene Kagera, Emily Kilonzi.

Agreement Number: 7200AA19CA00010/ Project Year 1 output
Project Start Date and End Date: July 31, 2019 to July 30, 2024
USAID Technical Office: Bureau for Food Security (BFS)/Office of Market and Partnership Innovations (MPI)
Agreement Officer Representative (AOR): Lourdes Martinez Romero

Submission Date: September 2020

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TABLE OF CONTENTS

ACRONYMS **5**
EXECUTIVE SUMMARY **6**
I. INTRODUCTION **7**
2. REVIEW METHODOLOGY **9**
2.1 Systematic Literature Review on foods 10
2.2 Systematic Literature Review on beverages (2000-2020) 10
2.3 Quality assessment 12
2.4 Data extraction and analyses 12
3. REVIEW FINDINGS **14**
3.1 DESCRIPTION OF REVIEWED ARTICLES **14**
3.2 DESCRIPTION OF STUDIES IDENTIFIED FOR INCLUSION IN REVIEW **16**
3.2.1 Review of foods 16
3.2.2. Review of beverages 17
3.3 HAZARDS REPORTED IN FOOD COMMODITY VALUE CHAINS **18**
3.4 HAZARDS REPORTED IN BEVERAGES **23**
4. DISCUSSION **27**
4.1 OCCURRENCE OF HIGH-BURDEN FOODBORNE DISEASE HAZARDS **27**
4.2 POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) **28**
4.3 BIOLOGICAL AND CHEMICAL HAZARDS IN READY-TO-EAT FOODSTUFFS **29**
4.4 STUDY LIMITATIONS AND RESEARCH NEEDS **29**
5. CONCLUSIONS **30**
REFERENCES **312**
APPENDIX 1. *PROTOCOL USED IN SLR FOR FOODS* **43**
APPENDIX 2. *SYNTAXES USED IN SLR FOR FOODS* **45**
APPENDIX 3. *PROTOCOL USED IN SLR FOR BEVERAGES* **45**
APPENDIX 4. SYNTAXES USED IN SLR FOR BEVERAGES [PUBMED] **47**
APPENDIX 5. SYNTAXES USED IN SLR FOR BEVERAGES [SCIENCE DIRECT] **47**
APPENDIX 6. *SYNTAXES USED IN SLR FOR BEVERAGES [GOOGLE SCHOLAR]* **48**
APPENDIX 7. *STUDY SUMMARY TABLE [FOOD]* **50**
APPENDIX 8. *STUDY SUMMARY TABLE [BEVERAGES]* **52**

List of Tables

Table 1. Diarrhoea disease agents (bacterial) associated with global FBD burden ---------------------------8
Table 2 Publication quality assessment criteria -- 12
Table 3. Priority Hazards in animal source foods --- 19
Table 4. Mycotoxin studies in nuts, seeds, beans and grains in Nigeria -------------------------------------- 22
Table5. Description of alcoholic beverages included in the review -- 23
Table 6. Description of non-alcoholic beverages included in the review ------------------------------------- 24
Table 7. Summary of bacterial hazards reported in beverages and frequency of occurrence ----------- 25
Table 8. Summary of chemical hazards reported in beverages and frequency of occurrence ----------- 26

ACRONYMS

Below is a list of all acronyms and abbreviations used in the report.

ASF	Animal Source Foods
AU	Africa Union
BMGF	Bill and Melinda Gates Foundation
DALYs	Disability Adjusted Life Years
FAO	Food and Agriculture Organization
FBD	Foodborne Disease(s)
FCT	Federal Capital Territory
FERG	Foodborne Disease Burden Epidemiology Reference Group
GDP	Gross Domestic Product
ILRI	International Livestock Research Institute
HACs	Heterocyclic Amines
LMICs	Low- and Middle-income Countries
NPC	National Population Commission
PAHs	Polycyclic Aromatic Hydrocarbons
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews
RTE	Ready-to- Eat
SLR	Systematic Literature Review
TEQ	Toxic Equivalents
UN	United Nations
UNECA	United Nations Economic Commission for Africa
USEPA	US Environmental Protection Agency
WHO	World Health Organization

EXECUTIVE SUMMARY

Food safety is important for better health, food security, and livelihoods. Foodborne diseases pose significant challenges all over the world and the burden is particularly high in low- and middle- income countries. This systematic literature review was undertaken to identify foodborne disease hazards in foods and beverages consumed in Nigeria. Findings will inform the scope of the risk assessment work planned as part of the project "EatSafe: Evidence and Action Towards Safe, Nutritious Food" which seeks to improve the safety of foods marketed through informal markets.

Two separate reviews were undertaken. One focused on hazard occurrence in foods consumed in Nigeria, the other on beverages (alcoholic and non-alcoholic). They are both combined here in this single review. Literature searches using agreed-upon keyword syntaxes were carried out in multiple databases including PubMed, CAB Direct, and Google Scholar. Titles and abstracts were screened, and the full text of publications meeting criteria for inclusion were reviewed. Structured quality assessment criteria were based on relevance and quality. Data from eligible publications were extracted into spreadsheets and summarized.

A total of 30 food (2017-2020) and 81 beverage studies (2000-2020) were examined in detail. The food analysis should be considered in conjunction with previous research done by ILRI (6). These studies were conducted in multiple Nigerian States including Ogun, Lagos, Nasarawa, Kaduna, and Oyo. Thirty-six separate food commodities were identified. The most frequently reported hazard was mycotoxins, which was reported across a variety of nuts, beans, cereals, and tubers. Several hazards were reported in animal source foods (ASF), among them *Staphylococcus aureus*, *Salmonella* spp., and pathogenic *Escherichia coli.* Chemical hazards reported in ASF were heavy metals (arsenic, cadmium, lead, cobalt), antimicrobial residues, and polycyclic aromatic hydrocarbons (PAHs). Only three studies on hazards in fruits and vegetables were identified. Bacterial and chemical hazards were the most reported hazards in beverages (67% and 17% of records reporting detection, respectively). No study on viral pathogens was identified.

It can be concluded from this preliminary scoping review that many foods and beverages consumed in Nigeria are associated with exposure of consumers to hazards of public health importance. However, the relative burden of hazards across different commodities would be difficult to estimate based on current evidence. Further analysis of the literature identified through this systematic review, complemented by new data collection, could inform formal risk assessments, which in turn can inform the prioritization and design of interventions to improve food safety in the country. Utilizing current best evidence as presented by the WHO-Foodborne Disease Epidemiology Reference Group (FERG) on the burden of foodborne

disease is recommended to guide the prioritization of future research and interventions, as little evidence of such prioritization has been identified in the review.

EatSafe is planning to conduct a risk assessment study to help determine the hazards whose control will yield the greatest benefits, and in selection of control interventions, for priority commodities. In addition, EatSafe is assessing the national and sub-national food control system to identify gaps found in legislation, policy and its implementation, and monitoring. Finally, EatSafe will consider involvement of all the relevant stakeholders, together with their access to tools and training required for achieving improved food safety.

1. INTRODUCTION

Food safety has been defined as the "assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use." Although access to safe food is a basic human right (1), foodborne diseases (FBD) continue to present significant health challenges all over the world. It is contamination with bacteria, viruses, parasites, foreign material, and chemicals that makes food unsafe for human consumption. Contamination can occur at any stage of the value chain; hence there is the need to consider a farm- to- fork approach when designing interventions to mitigate the risks. Children, pregnant women, the elderly, and the immuno-compromised are at higher risk of acquiring food related diseases and experiencing severe effects(2). According to the 2010 estimates by the World Health Organization, about 600 million people become sick each year and 420,000 die, resulting in an estimated FBD burden of 33 million Disability Adjusted Life Years (DALYs) (3). The metric (1 DALY) is equivalent to one year of "healthy" life that is lost.

Food safety can greatly impact food security and nutrition. It has been said that there cannot be food security without food safety (1). The link with nutrition is less defined. Malnutrition can increase an individual's susceptibility to infections (4) including diarrhea, and unsafe food interferes with uptake of nutrients (1) worsening the malnutrition, and impacting on developmental outcomes in children (2). Food safety is also important for development. Addressing the twin problems of malnutrition and food safety has the potential to facilitate attainment of United Nation`s Sustainable Development Goals including "no poverty", zero hunger, and promoting health and wellbeing of communities.

The best estimates of foodborne disease burden in Africa are those provided by the World Health Organization (2,6). The Foodborne Disease Burden Epidemiology Reference Group (FERG) was convened in 2007 to estimate the global burden of diseases commonly transmitted through food. The study found the burden to be particularly high in children under five years of age. Also, 54% of the total burden was attributed to diarrhoea disease agents (**Table 1**). About 90% of food-poisoning illnesses are believed to be caused by species of *Staphylococcus, Salmonella, Clostridium, Campylobacter, Listeria, Vibrio, Bacillus,* and *Escherichia coli* (14). The majority of foodborne diseases result from consumption of animal source foods and fresh vegetables (15). Pathogens with animal reservoirs are responsible for a higher proportion of illnesses attributable to food compared to those with human-to-human transmission or waterborne transmission (16).

Table 1. Diarrhoea disease agents (bacterial) associated with global FBD burden

	DALYs	Number of diseases	Number of deaths
Non-typhoidal *S enterica*	4,067,929	78,707,591	59,153
Enteropathogenic *E. coli*	2,938,407	23,797,284	37,077
Campylobacter spp.	2,141,926	95,613,970	21,374
Enterotoxigenic *E. coli*	2,084,229	86,502,735	26,170
Vibrio cholera	1,722,312	763,451	24,649
Shigella	1,237,103	51,014,050	15,156
Shiga toxin *E. coli*	12,953	1,176,854	128

[a] Source: Havelaar *et al*., 2015 (3)

Assuring food safety is not easy. It is the responsibility of governments to ensure available foods are safe for human consumption. This has mostly been achieved through strengthening of food control systems. Attention to food safety has particularly been low in LMICs where the risk is perceived to be high. The WHO report (2) notes that even visible outbreaks may go unrecognized, unreported , and not investigated. Food safety tends to capture national attention only when there is a crisis (7), especially one that is likely to result to a major public health or economic impact (2).

The FBD risk prioritization processes needed to allocate resources effectively have been lacking in Nigeria. Surveillance is an important component of food control systems. In addition to allowing for early detection of disease outbreaks, the data can be used to assess disease burden and trends over time, target interventions, and ensure that countries allocate available resources efficiently and effectively. However, surveillance systems in many developing countries face a number of challenges including weak laboratory capacities and scarce resources (22) (23). Improved surveillance systems have received minimal support in public health planning.

The WHO AFR-D region[1] was identified by the FERG report to experience the highest burden of FBDs at 1,276 (459-2,263) DALYs per 100,000 populations (3). Nigeria, the most populous country and the largest economy on the African continent, is considered to have a particularly high health and economic burden attributed to FBDs. Productivity losses attributed to FBDs in Nigeria in 2016 were estimated by the World Bank to be over $6 million (7).

Nigeria also experiences a significant burden of malnutrition. According to the 2018 demographic and health survey (24), 37% of children aged 6-59 months are stunted. Stunting

[1] AFR-D includes Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo

is most prevalent in Kebbi State (66%). The infant mortality rate was 67 deaths per 1,000 live births for the 5-year period preceding the survey (under 5-year-old mortality was 132 deaths per 1,000 live births). The under-5 mortality rate is also highest in Kebbi (252 deaths per 1,000 live births). Hygiene and sanitation standards in the country are low (open defecation was reported in 25% of the households surveyed) and only 66% of households have access to an improved drinking water source(24). The GDP of Nigeria in 2019 was estimated to be $2,222 per capita, although 60% of the population was living below the poverty line in 2010 (25,26). The population of Nigeria, estimated at 182.2 million in 2015, is expected to reach 229 million by 2025 (25), and 400 million by 2050 (27).

In order to inform the development of interventions for the improvement of food safety within informal market settings, this Systematic Literature Review (SLR) was undertaken to synthesise the current evidence on foodborne hazard occurrence in foods and beverages consumed in Nigeria. The evidence synthesised will be a key input for risk modelling activities (a research activity under the "EatSafe: Evidence and Action Towards Safe Nutritious Food"). Through risk modelling, the risk associated with consumption of selected foods will be determined, and potential mitigation steps identified. An understanding of the relative importance of exposure sources can aid in targeting interventions and control measures, and in informing decisions on where to direct resources to achieve greater health benefits (16).

A report on foodborne hazards in Nigeria for the years 1990-2017 was produced by ILRI under a study commissioned by the Bill and Melinda Gates Foundation (BMGF), and was leveraged for this present study (6). Within this past study, 110 manuscripts were eligible for inclusion, although only 15% of the included studies were evaluated as being of good quality according to similar criteria as applied here, demonstrating a potential lack of capacity within food-safety research in Nigeria. Many of these studies were concerned with the prevalence of foodborne hazards in food, with a small proportion considering prevalence of foodborne disease in humans and the economic impact of such. Of the priority diarrheal pathogens identified by the FERG, non-Typhoidal *Salmonella* spp. and toxigenic *E. coli* were both identified in foods including fruits, beef products, and smoked fish.

It was not apparent from this review that research on food-safety had been guided by a systematic approach to prioritising risk (6). The SLR presented here, produced within the EatSafe programme, expands upon this report to capture data produced up to 2020, and adds newly synthesized evidence on beverages consumed in the country.

2. REVIEW METHODOLOGY

Two separate systematic literature reviews were undertaken. Both are presented here in this single review. One focused on hazard occurrence in foods consumed in Nigeria, and the other on beverages, both alcoholic and non-alcoholic. Both SLRs followed the established "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) guidelines. The protocol for the SLR on beverages was published in PROSPERO with "Occurrence of foodborne disease (FBD) hazards in beverages consumed in Nigeria" as the title and

“CRD42020184768” as the registration number. For the foodborne hazard SLR, the protocol for the 2010-17 review was utilised (and registration is being pursued).

2.1 Systematic Literature Review on foods (2017-2020)

The protocol developed for a previous SLR covering the period 1990-2017 was adapted for use in this review (Appendix 1). The inclusion criteria considered publications published between 2017- 2020 reporting on foodborne hazards identified in Nigeria (including biological and chemical hazards including antimicrobial residues). Publications were included if published in English, and if they were either observational studies, secondary data analyses, or literature reviews. We excluded studies that were conducted outside Nigeria, those focused on non-foodborne illnesses / hazards, studies not considering biological or chemical hazards associated with foods, as well as any experiments, and studies solely on antimicrobial resistance. Studies that involved analyses of faeces and serum from animals, or carriage in vectors, were also excluded.

Searches were done in PubMed and CAB Direct databases (Appendix 2). We downloaded the titles and abstracts and removed any duplicates found. Four reviewers participated in the title and abstract screening. Each article was screened by two people. Five reviewers participated in the full article review and data extraction process. A full paper was included if at least one of the reviewers recommended it for inclusion. The first 12 publications were reviewed in 4 rounds (by four reviewers); 3 publications were considered in each round of review. Areas of disagreements were discussed until an agreement was arrived at. The remaining publications were shared among three reviewers (two had participated in the review of the 12 publications). Some publications were excluded during data extraction. This report focuses on the newly identified studies covering the 2017-2020 period.

Research questions for the review on foodborne hazards include:

- What hazards (biological and chemical) have been identified in food products consumed in Nigeria?
- What is the prevalence (% of contaminated products) of hazards in specific commodities in Nigeria? Identify data that can support risk ranking of FB hazards using a risk-based approach (separate effort).
- What is the incidence of foodborne disease in Nigeria (annual number of clinical cases, annual number of deaths attributed to food)?
- What is the health burden (DALYs; % of symptomatic cases; severity; mortality; hospitalization; duration of illness; long-term sequelae) of foodborne disease in Nigeria?

2.2 Systematic Literature Review on beverages (2000-2020)

A protocol was developed (Appendix 3) and used to guide the review process (PROSPERO reg no. CRD42020184768 which searchable in https://www.crd.york.ac.uk/prospero/ using the following key word combination: (foodborne disease) AND hazards AND beverages AND Nigeria). Observational studies, secondary data analysis, and literature reviews on beverage-associated hazards (biological and chemical) conducted in Nigeria were considered. Studies published between 2000-2020 written in English were included in the review. The exclusion criteria included studies conducted outside Nigeria, those on non-beverage associated illnesses / hazards, studies not considering biological or chemical hazards associated with beverages, experiments, and antimicrobial resistance. Studies that involved analyses of faeces and serum from animals, or carriage in vectors, were also excluded.

Key words were defined and combined into syntaxes. Some key words were the same ones used in the food SLR. Searches were conducted in three online databases (PubMed, Science Direct and Google Scholar). Syntax is available in Appendices 4, 5, and 6. Because Science Direct has a word limit of 8 boolean operators, and to ensure inclusion of all the beverage and safety words in the PubMed syntax, we developed a series of 40 syntaxes and ran them in Science Direct. The results were combined into one file, treated as a single output from Science Direct. The publications were exported to Mendeley, where duplicates were identified and removed. Google scholar (GS) has a character limit of 256, and to allow for inclusion of all the beverage and safety words in the PubMed syntax, we developed a series of 20 syntaxes and ran them in GS Advanced Search. The search results were exported to Mendeley using its web importer function where they were combined into one file (which was treated as a single output from GS) after identification and removal of duplicates. Article titles from the first 300 search results were retrieved per syntax (28).

The review was led by two people (reviewer 1 and 2) supported by reviewer 3 and 4. For each database, the first stage was a download of titles and abstracts from search results and exporting the outputs to Mendeley, from where duplicates were assessed and removed. Individual files representing each database were uploaded to Rayyan QCRI software (https://rayyan.qcri.org/). Rayyan QCRI software was utilized in the screening of titles and abstracts. Reviewer 1 hosted the review while reviewer 2 was added as a collaborator, to independently screen the articles. Reviewers 3 and 4 were invited to monitor the screening process. Duplicates were removed when found. Reasons for exclusion were indicated.

Areas of conflict were identified and resolved, through a discussion by the two reviewers, who agreed to either accept or reject the abstracts. A third person reviewed publications where the two reviewers could not agree and decided on accepting or rejecting. Accepted abstracts were those judged as acceptable by at least two of the reviewers. Full paper screening was also aided by *Rayyan QCRI software*. The publications were downloaded and independently reviewed by reviewer 1 and 2. Any discordance in classification was addressed by a third reviewer. A random sample of 5% of the included and 5 % of the excluded publications was also reviewed by a third reviewer. Accepted full publications were those judged as acceptable by at least two of the reviewers. Research questions identified for the review on beverages include:

- What hazards (biological/chemical) have been identified in beverages consumed in Nigeria?
- What is the prevalence (% of contaminated products) of hazards in certain commodities in Nigeria and what is the spatial distribution of these hazards?
- Incidence (annual n. of clinical cases, annual n. of deaths resulting from beverage-associated hazards) of beverage-borne disease in Nigeria
- Health burden (DALYs; % of symptomatic cases; severity; mortality; hospitalization; duration of illness; long-term sequelae) of beverage-borne disease in Nigeria
- Is it possible to produce a prioritized list of beverage-associated hazards in Nigeria based on a risk analysis approach?

2.3 Quality assessment

Subjective quality assessment criteria were used to determine suitability of studies for inclusion (Table 2). Scoring based on these three quality categories (good, medium, poor) was done for each criterion by the review team (all with epidemiological training at post-graduate level). Scores for the four criteria were combined into one overall score for the publication. Publications that were deemed of "good" or "medium" quality were included in the final set for data extraction (Figures 1 and 2). This review of individual publications was carried out before data were extracted, to ensure that publications perceived to be of poor quality were excluded from the study.

Table 2 Publication quality assessment criteria

Good	Medium	Poor
Unbiased selection of subjects/samples (probabilistic sampling)	Biased sampling acknowledged and accounted for	No acknowledgement of biased sampling process
Methods are scientifically sound and accurately described	Limitations in data analysis are acknowledged and accounted for	Data analysis inappropriate for research question proposed
Data analysis judged to be appropriate for the research question	Some details on methods are lacking but methods are understandable and sound	Methods unclear or incomplete
Reported results are complete and appear to be valid	Reported results appear to be valid, although may not be fully complete	Reported results are incomplete or obviously inaccurate

2.4 Data extraction and analyses

For the beverage SLR, an Excel® template was designed into which relevant data were extracted. Pre-testing of data extraction was done by 2 reviewers extracting data from a subset of the publications (5-10%) and comparing the data extracted. This activity not only provided an opportunity to validate the template, but also to ensure that researchers extracting the data were conversant with its use and understood the outcomes of interest. Weekly meetings allowed the teams opportunities to discuss progress and any challenges faced (e.g. in the case where reviewers encountered publications that were not clear on the data to extract). Entries by all reviewers were combined into one database. Validation of the entries was done by two additional reviewers and reviewing entries for 10-15% randomly selected publications. Table 3 provides a highlight of data extracted in the review. A more detailed summary of study characteristics, publication by publication, is provided in Appendices 7 and 8.

Table 3: Types of data extracted during SLR review on foodborne hazards in food and beverages consumed in Nigeria

Food	Beverages
• Geographical location • What was studied: e.g. prevalence in food, prevalence in environment, incidence in humans, health impact, social impact • Type of study: cross-sectional, cohort, case-control, field experiment, outbreak investigation, review of literature, review/meta-analysis of secondary data • Target population or items sampled: food, animal, humans, carcasses etc. • Specify the food value chain: animals, crops • Production system: extensive, intensive, pastoralist, etc. • Category of the hazards: biological, chemical • Specify the name of the hazard • Food samples analyzed • Diagnostic tests or assays used • Number of samples analyzed • Number of positive samples • Burden or other hazard impacts	• Geographical location • Type of study • Name of the beverage • Category of the hazards • Specify the name of the hazard • Point of sampling (retail, point of consumption, etc.) • Sampling method used • Diagnostic tests used • Number of samples analyzed • Number of samples that tested positive • Raw data on the concentration of the hazard

In the context of these reviews, the following outcome terms are used:

- Number of publications: a publication is a published article;
- Number of records: a record is the finding about a specific hazard and food category pair; a publication may contain multiple records (e.g. results on *Salmonella* and *E. coli* O157:H7 in beef from the same publication would constitute two records);
- Number of positive records: number of records that report detecting the hazard under consideration (compared to records reporting no detection).

Unless otherwise specified, results are presented in terms of number of publications of number of records where discussing research production and evidence availability, and in terms of number of positive records when discussing the content of the reviewed publications.

3. REVIEW FINDINGS

3.1 Description of reviewed articles

A summary of the number of publications considered at each stage of the review is given in Figure 1 (food) and Figure 2 (beverages).

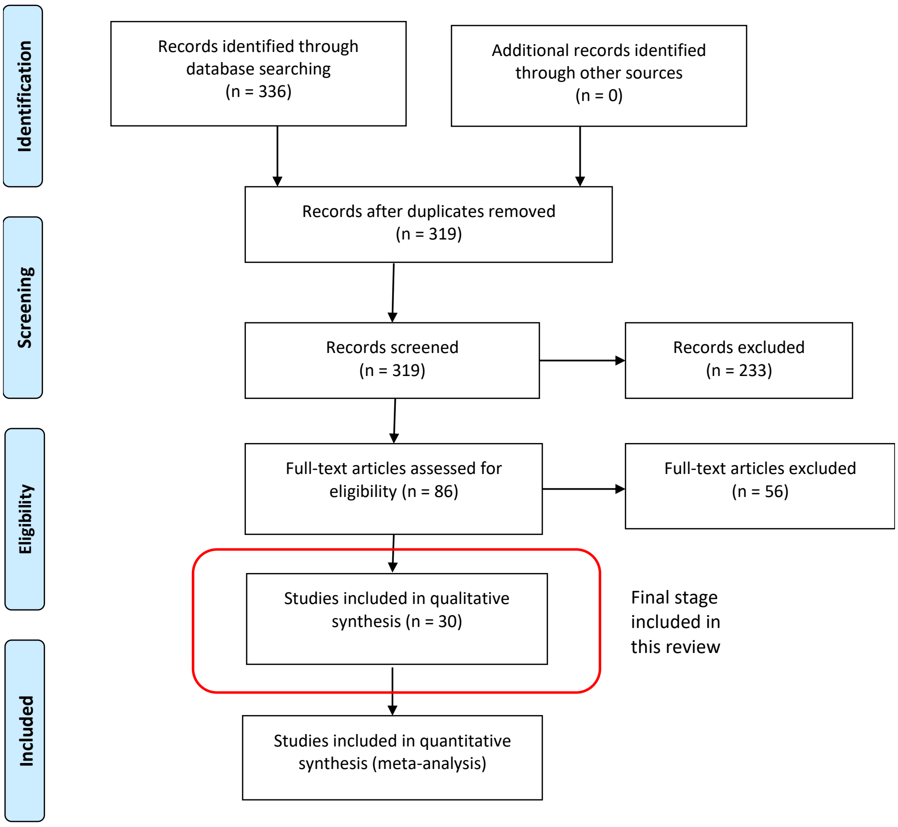

Figure 1: Number of publications included at each stage of the food SLR process

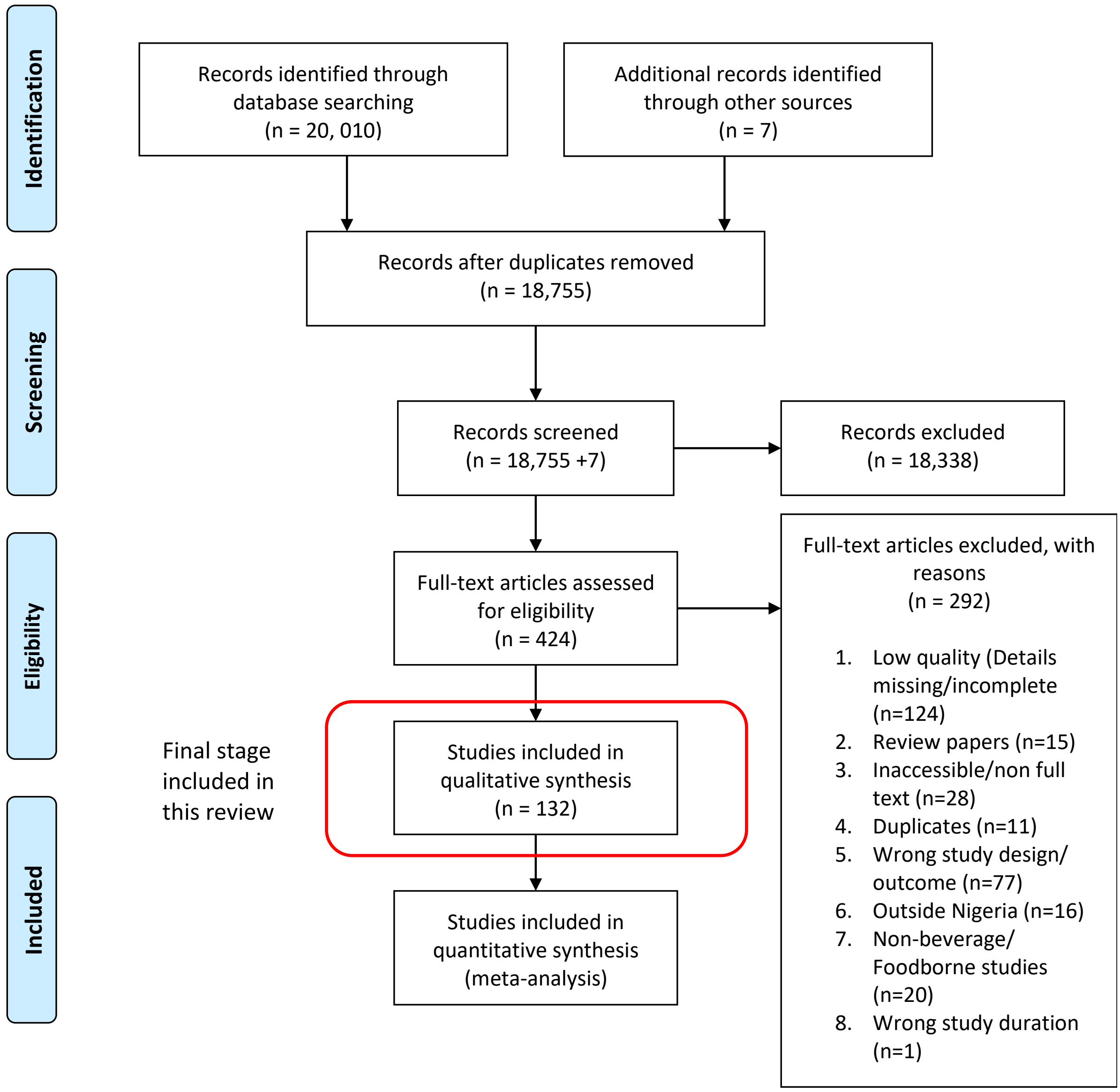

Figure 2: Number of publications included at each stage of the beverage SLR prcess

3.2 Description of studies identified for inclusion in review

3.2.1 Review of foods

A total of 86 studies were included for full text screening, after exclusion of ineligible and poor-quality studies, 30 publications were available for data extraction. A summary of these manuscripts is provided in Appendix 7.

In line with international publication trends, the number of eligible studies on food-safety in Nigeria identified for review has been demonstrating a general upward trend over the 30-year period as shown in **Figure 3**. This figure shows data from this study and from the previously conducted SLR on food (6).

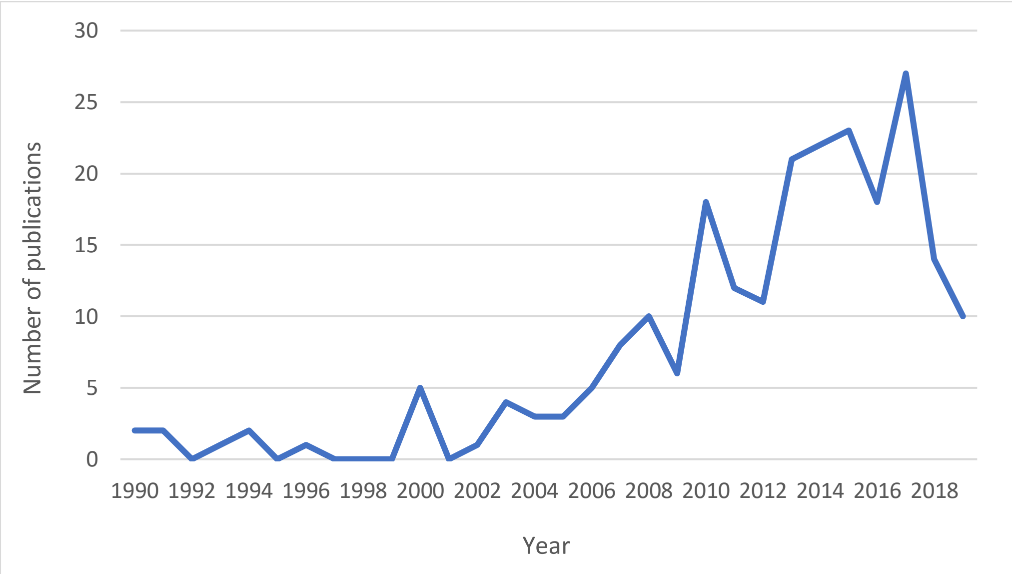

Figure 3: Number of eligible food safety publications by year: food

The geographical location (Nigerian states) covered in the 30 included manuscripts included 15 of the 36 states of Nigeria, although most studies have been conducted in Lagos, Ogun, and Oyo states (Figure 4).

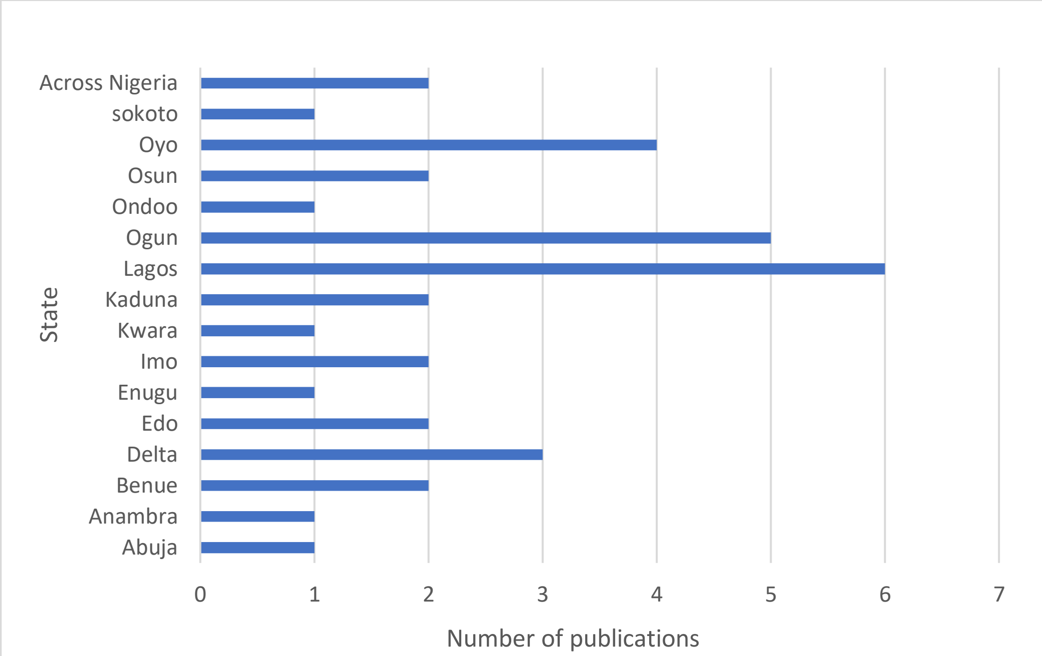

Figure 4: Number of food studies by state

3.2.2. Review of beverages

A total of 181 publications were selected for full-text screening. Data from 81 publications are considered here. The data extraction table can be found in Appendix 8.

As for the food review, an upward increase in the number of publications can be seen, with an observable peak in 2014. A gradual decline is seen in the last 5 years (Figure 5).

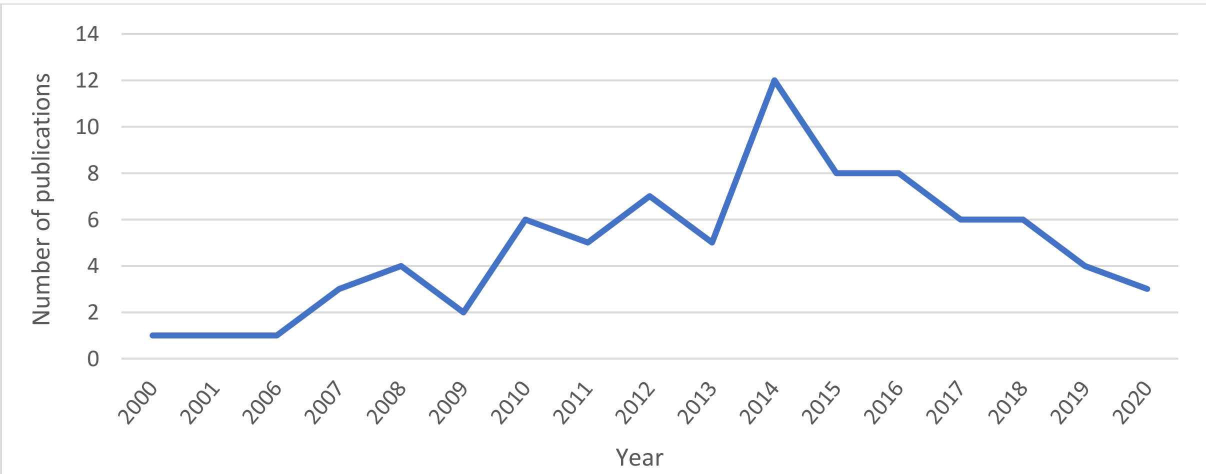

Figure 5: Number of eligible food safety publications by year: beverages

The majority of the studies was conducted in Kaduna (14%), Oyo (7%), and Ogun (6%) States (**Figure 6**). “Multiple” implies studies that covered several states.

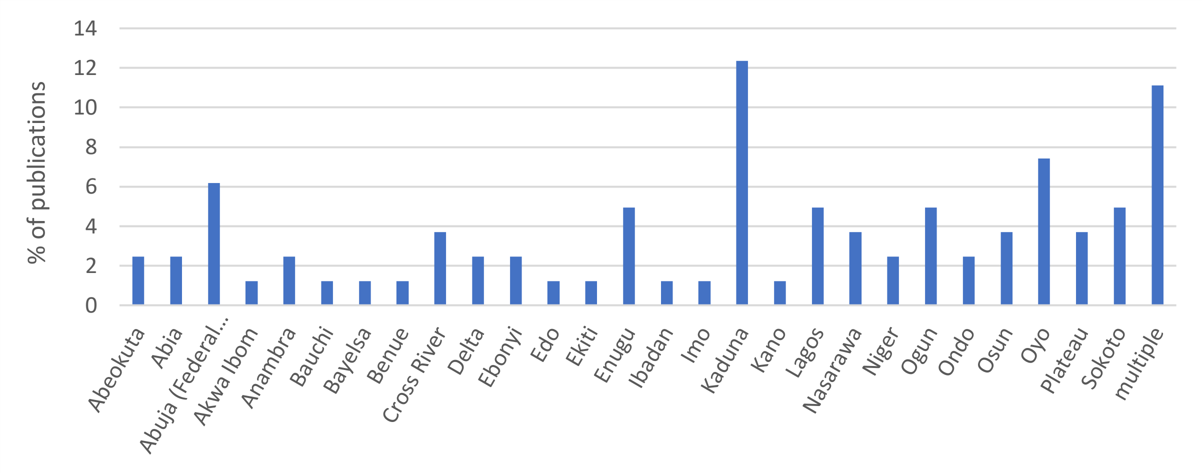

Figure 6: Number of beverages studies per state

3.3 Hazards reported in food commodity value chains

Thirty-six (36) separate commodities were identified in the 2017-2020 literature review. The most frequently investigated product was maize and its derivatives (e.g. ogi, a fermented cereal pudding) and fish (fresh, grilled and smoked), covered in four manuscripts, followed by beef and pork (3 publications). Milk and ready to eat (RTE) shrimps were each covered in 2 publications.

The most common foodborne hazards studied were mycotoxins (reported in groundnuts, infant formula and powdered milk, maize and its derivatives, peanut butter, sesame, soybean and Bran), followed by *Bacillus cereus* (reported in: beef, fish, green pea, rice, RTE shrimp, meat products and spaghetti), and coliforms (milk, fish and seafood, meat products and peanut butter). A summary of all commodity categories and the hazards identified in each is given in Table 4.

3.3.1 Hazards identified in animal source foods

The majority of studies on animal source foods were focused on biological hazards, predominately microbiological contamination, with two studies considering the zoonotic parasite *Taenia solium*, and the protozoa *Toxoplasma gondii*. Several studies utilised microbial load or coliform count as an indicator of contamination.

Several studies focussed on some of the key microbial hazards associated with diarrheal disease (*Staphylococcus, Salmonella, Vibrio, Bacillus,* and *Escherichia coli*) in animal source food products in Nigeria. Sampling strategies were not always appropriate to understand the risk to the consumer and many studies had small sample sizes, which makes extrapolation of prevalence of microbial contamination of animal source foods difficult. Studies on priority microbial pathogens in animal source products are summarised in Table 4.

Table 3. Priority Hazards in animal source foods

Publication	Commodity	Hazard	Sampling point	Contamination prevalence/ Comments
Adikuwu et al. (29)	Pork	*Staphylococcus aureus*	Abattoir	25% in carcasses and meat
Odetokun et al. (30)	Beef, goats, sheep	*Staphylococcus aureus*	Abattoir	6.4%
Agbaje et al. (31)	Poultry	*Salmonella spp.*	Retail	28%
Olalemi (32)	Catfish	*E. coli* Faecal coliforms Intestinal enterococci *Salmonella* spp. *Shigella* spp.	Within raising pond	Investigated bioaccumulation rates and association with temperature and water characteristics
Okoli et al. (33)	Roasted meat (beef, pork, chicken, goat)	*Staphylococcus* spp. (*S. sciuri, S. lentus, S. saprophyticus, S. carnosus, S. piscifermentans, S. epidermidis*)	Retail	9.4%. Beef most commonly contaminated. 10% isolates multi-drug resistant
Yakubu et al. (34)	Milk (raw and fermented)	Shiga Toxigenic *Escherichia coli* O157:H7	Farm (raw) Retail (fermented)	1.86% (raw) 2% (fermented)
Beshiru et al. (35)	Shrimps (ready to eat) – 1440 samples	*Salmonella* spp. (*S.* enteritidis*, S.* typhimurium*,* other serotypes)	Retail	15%
Beshiru et al. (36)		*Vibrio* spp. (*V. parahaemolyticus, V. vulnificus, V fluvialis, V. alginolyticus, V. cholera, V. mimicus, V. harveyi,* other spp.)		93.3%, studied biofilm production, virulence potential, autoaggregation and coaggregation
Adesetan et al. (37)	Meat and fish (fired or smoked)	*Bacillus cereus*	Retail	36%
Oranusi et al. (38)	Fish (ready to eat)	*Staphylococci*, *Bacillus* spp.	Retail	Prevalence of isolates not reported

Chemical hazards studied in relation to animal source foods included heavy metals in beef sausages and fish, antimicrobial residues in eggs and Polycyclic Aromatic Hydrocarbons (PAHs) and Heterocyclic amines (HACs) in beef sausage rolls, smoked meat, hide and fish products. A majority of the PAHs and HACs are highly potent carcinogens and are introduced into foods through smoking and roasting processes (38), whilst exposure to non-carcinogenic

PAHs at high concentrations can lead to diarrhoea, vomiting, haematuria, kidney damage and respiratory issues. 16 PAHs were designated as high priority pollutants in 1976 by the US environmental protection agency (USEPA) (39). Twelve of the 16 USEPA priority PAHs were detected singly or in combination within samples of grilled or smoked fish and meat from Lagos and Ogun States and a single HAC (2-amino-1-methy-6-phenylimidazo[4,5-b]pyridine) was detected in these samples (38). All the 16 priority PAHs were detected in beef sausage rolls from Osun state (40). The carcinogenic toxic equivalents (TEQ) of the PAHs in the sausage roll samples were calculated and estimated to be between 57-322 ug TEQ/g indicating a high potential for carcinogenic health effects of regular consumption. Arsenic, cadmium, lead and cobalt were also all detected in beef sausage rolls at levels above the recommended exposure limits (40). Zinc, manganese, lead, cadmium and iron were all present in fish purchased from fishermen in the Lagos lagoon at levels exceeding recommended exposure limits (41). Carcinogenic and non-carcinogenic health risks were calculated from exposure to PAHs and heavy metals in sausage rolls and fish. The Health Risk Index of cadmium and arsenic from some sausage roll samples were found to be over 1, whilst the target hazard quotient of heavy metals in fish samples was found to be <1 for all samples (40,41).

Only a single study considered antimicrobial residues in animal source foods. It found egg samples in Lagos and Oyo states to have contained antimicrobial residues above levels recommended for human consumption (42). Antimicrobial residues in food are a public health concern particularly in relation to the emergence of antimicrobial resistance, although there is also a risk of rare hypersensitivity reactions.

3.3.2 Hazards identified in fruits and vegetables

Food safety within the class of fruits and vegetables is the least studied commodity group amongst identified studies, with only few manuscripts detailing hazard identification within this class. One study considered microbial load and the presence of *Bacillus cereus* in vegetables purchased in Ogun state (37). In another, a selection of fruits both locally grown (guava, pineapple, orange, and pawpaw) and imported (apples) were sampled from Anambra state and analysed for the presence of heavy metals. They were found to have arsenic levels over the maximum food-grade limit under Codex Alimentarius and that apples and guava had mercury levels over recommended limits (43). The hypothesis is that airborne pollutants may deposit heavy metals on fruits displayed for sale, if not well protected. The final study in this class considered microbial and chemical hazards in ready-to-eat (RTE) products sold in Ogun state. Roasted yam and roasted plantain were found to be contaminated with *Bacillus cereus*, *S. aureus*, *Pseudomonas* spp. and *Proteus* spp. Fungal growth was detected in the plantain samples. The roasting process was found to be associated with the presence of PAHs in the yam and plantain samples, although fewer of the priority PAH compounds were detected in these than in the meat and fish sampled in the same locality (44).

3.3.3 Hazards identified in nuts, seeds, beans, and grains

Mycotoxins were the predominant hazard studied within this commodity class with 7 publications identified as outlined in Table 5. In addition to moulds including *Aspergillus* spp.

associated with the production of mycotoxins, cassava flour (Garri) purchased from two markets in Benue state was found to also be contaminated with *E. coli*, *Salmonella* spp., *S. aureus* and *Shigella* spp. (52). *Bacillus cereus* was identified in samples of ready-to-eat rice purchased in Ogun state (37), while bean samples purchased in Imo state were determined to pose low arsenic risk (53).

Table 4. Mycotoxin studies in nuts, seeds, beans and grains in Nigeria

Commodity	State	Comment	Reference
Paired Grains and prepared meals (maize, cassava, rice)	Kaduna and Nasarawa	Substantial reduction in mycotoxins between paired samples after processing but risk of exposure still estimated to be high	Ezekiel et al. (45)
Groundnuts (peanut) and Cashew nuts	Lagos	Risk of liver cancer estimated to be 1.38 (groundnuts) 0.01 (cashews) cancer $year^{-1}100{,}000^{-1}$persons	Adetunji et al. (46)
Maize and maize products		Thirty seven percent of maize sampled at harvest (n=8) had aflatoxin levels above the required total aflatoxin limit (4µg/kg); while 87.5% (n=8) of samples taken after four months of storage had levels above the limit.	Liverpool-Tasie et al. (47)
Sesame and Soya bean	Abuja (FCT)	Mycotoxins were found to be within regulatory limits other than Ochratoxin A (which had a median contamination of 16.8ug Kg with a maximum concentration of 23.1ug/kg). The tolerable limit in Nigeria is 5ug/kg	Fahohunda et al. (48)
Infant foods	Lagos and Ogun	Majority of complementary foodstuffs found to be above recommended levels.	Ojuri et al. (49)
Groundnuts	Across Nigeria	Mean total Aflatoxin of 216.ug/kg substantially above 4ug/kg Nigeria maximal limit. Potential risk to consumers	Oyedele et al. (50)
Cassava Products	Across Nigeria	Risk to consumers assessed to be minimal	Abass et al. (51)

3.4 Hazards reported in beverages

The included publications (n=81) yielded 524 records. Both alcoholic or non-alcoholic beverages were considered; 36 were alcoholic, 482 were non- alcoholic, and 6 were not defined. Alcoholic beverage types observed in the review, and the proportion of available records on each, are shown in Figure 7 and further explained in Table 6. Nine of the records (25%), reported as either "alcoholic" drink without further specification, or local or imported beer, are labelled as "alcoholic" in the figure.

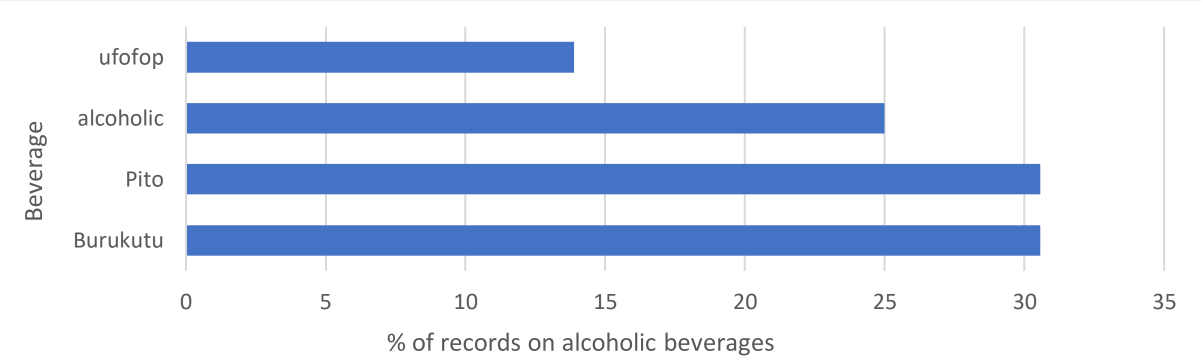

Figure 7: Reviewed research on alcoholic beverages consumed in Nigeria (n=36 records)

Table 5: Description of alcoholic beverages included in the review

Name of the production	Description
Ufofop	Ufofop is a local gin and a distillate of the palm wine (54).
Pito	Pito is brewed from sorghum or maize malts. Its traditional preparation method is as described by Orji et al. (55); sorghum grains are soaked overnight, then poured into a basket, and the water is allowed to run off for about 2h. The grains are then spread out on leaves or mats and covered with an additional layer of leaves. Germination is done for 4–5 days.
Burukutu	Burukutu is a traditional cereal-based alcoholic beverage (56). It can be produced from millet and sorghum. Burukutu is popular in cultural ceremonies and is also an income source (especially for rural women who participate in its production).

The non-alcoholic products (n=482 records) included water, milk, and various other locally consumed products (**Figure 8**; **Table 7**).

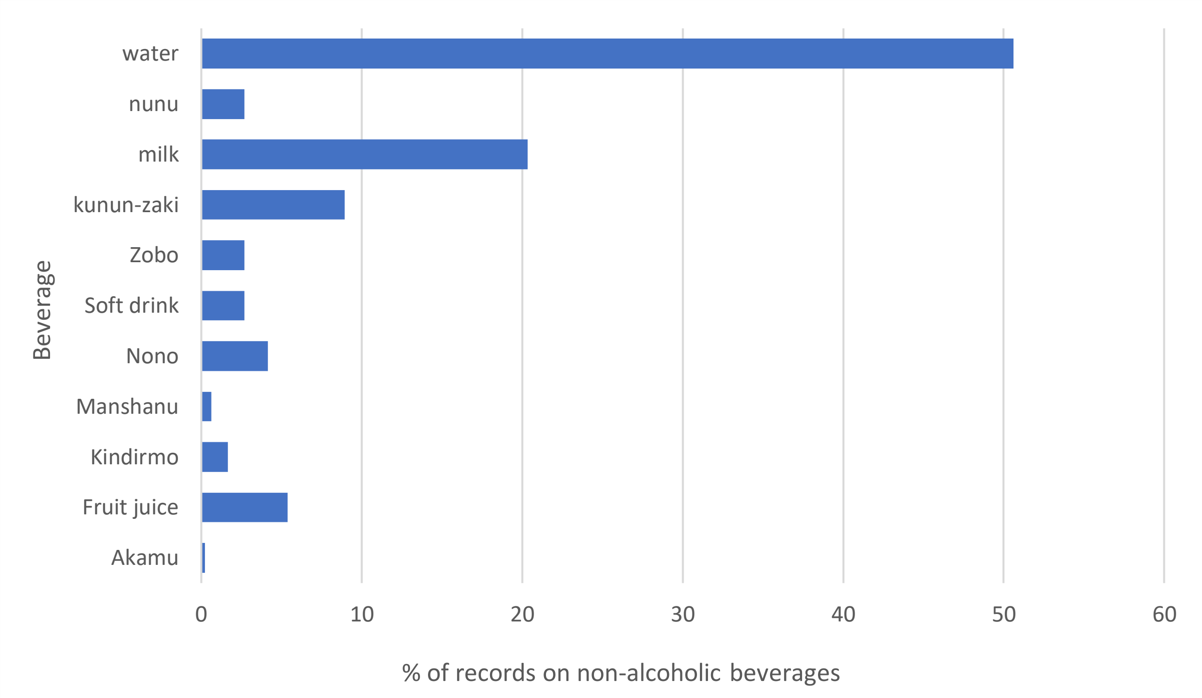

Figure 8: Reviewed research on non-alcoholic products consumed in Nigeria (n=482)

Table 6: Description of non-alcoholic beverages included in the review

Name of the product	Description of the product
Nunu	Spontaneously fermented yoghurt made from cow milk; milk is put into containers and allowed to ferment for 1-2 days (57).
Kunun- zaki	Cereal-based non-alcoholic fermented beverage, produced by steeping of sorghum, millet or maize, wet milling, sieving and partial gelatinization of the slurry. It can be consumed any time of the day (58).
Zobo	Zobo is a hot water extract of *Hibiscus sabdariffa* (59). It has a sour taste. Traditionally, women produce it at small scale (59).
Nono	Susan *et al*. (60) describe “nono” as a crude cultured whole milk. Nono is produced by nomadic Fulani people (61). It is sold by Fulani women and when mixed with cereal it can be used as food, drink, and weaning food (62).
Manshanu	Manshanu is a traditionally fermented milk product (63).
Kindirmo	Kindirmo is a full fat or partially skimmed cultured milk (60).
Akamu	Porridge from fermented maize, used for breakfast, also for infant weaning (64). It is also made from millet and sorghum.

Thirty-six (6%) beverage records did not specify the hazard type (but provided indications on quality) and 86 reported negative (non-detected) test results. The number of records with positive findings (hazard detected) was 402, and included: antimicrobial residues (0.5%), bacteria (67%), mycotoxins (5%), chemicals other than mycotoxins (17%), fungi (7%), and parasites (3.5%). For bacterial contamination (n=269 positive records), *Escherichia coli* (17%), *Staphylococcus* (15%), and *Salmonella* (12%) were the main pathogens observed (Figure 9).

Most positive records were on milk (29%; n=289) and water (43%). Chemical hazards (n=67) including heavy metals were also reported (Table 8, Table 9).

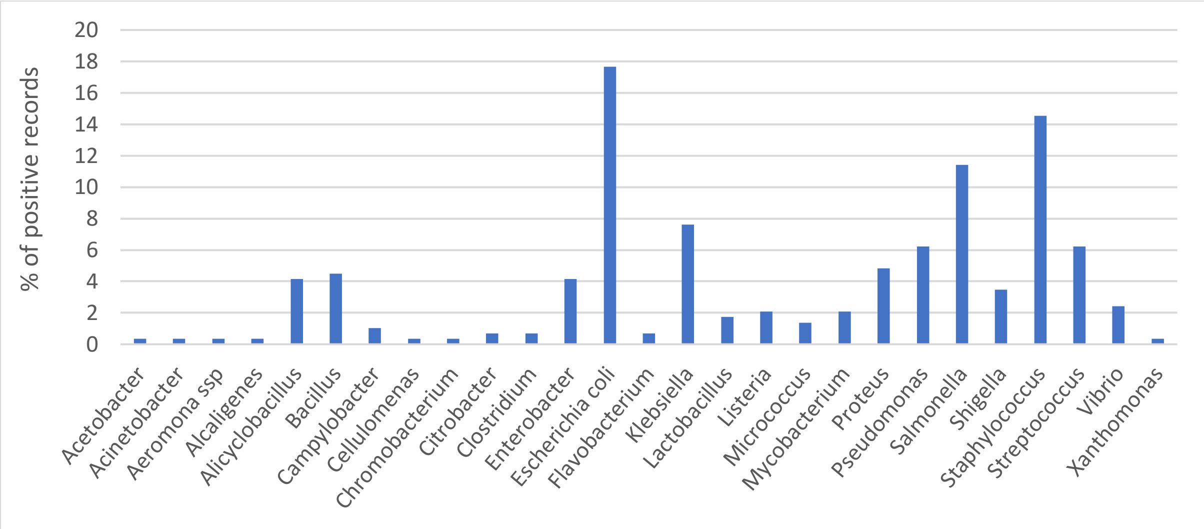

Figure 9: Bacterial hazards reported in beverages (n=269 positive records)

Table 7. Summary of bacterial hazards reported in beverages and frequency of occurrence

Type of product (%; n=269)	Bacterial contaminants (number of records reporting detection) [b]
Milk (n=80, 29%) [a]	Bacillus (5); Cellulomenas (1); Clostridium (1); Citrobacter (1); Clostridium (2); *Escherichia coli* (14); Klebsiella (5); Lactobacillus (2); Listeria (6); Micrococcus (1); Mycobacterium (3); Proteus (1); Pseudomonas (4); Salmonella (10); Shigella (2); Staphylococcus (17); Streptococcus (5); Xanthomonas (1)
Fruit juice (n=14, 5%)	Acetobacter (1); Alicyclobacillus (9); Bacillus (1); Enterobacter (1); Lactobacillus (1); Staphylococcus (1)
Kindirmo (n=8, 3%)	*Escherichia coli* (1); Salmonella (2); Staphylococcus (4); Streptococcus (1)
Manshanu (n=3, 1%)	*Escherichia coli* (1); Salmonella (1); Streptococcus (1)
Nono (n=18, 6%)	Bacillus (1); *Escherichia coli* (2); Mycobacterium (2); Pseudomonas (1); Salmonella (3); Shigella (1); Staphylococcus (7); Streptococcus (1)
Zobo (n=3, 1%)	Bacillus (2); Citrobacter (1); *Escherichia coli* (4); Klebsiella (1); Lactobacillus (2); Proteus (1); Pseudomonas (2); Salmonella (2); Shigella (1); Staphylococcus (4); Streptococcus (2)
Kunun-zaki (n=22, 8%)	*Escherichia coli* (8)
Nunu (n=8, 3%)	Acinetobacter (1); Aeromona (1); Alcaligenes (1); Bacillus (4); Campylobacter (3); Chromobacterium (1); Enterobacter (11); *Escherichia coli* (14); Flavobacterium (2); Klebsiella (14); Micrococcus (3); Proteus (11); Pseudomonas (8); Salmonella (14); Shigella (5); Staphylococcus (8); Streptococcus (7); Vibrio (5).
Water (n=113, 42%)	Bacillus (5); Cellulomenas (1); Clostridium (1); Citrobacter (1); Clostridium (2); *Escherichia coli* (14); Klebsiella (5); Lactobacillus (2); Listeria (6); Micrococcus (1); Mycobacterium (3); Proteus (1);

	Pseudomonas (4); Salmonella (10); Shigella (2); Staphylococcus (17); Streptococcus (5); Xanthomonas (1)

[a] Percentages in the left-most column refer to the number of positive records, i.e. records reporting detection, for each product over a total of 269 positive records on bacterial hazards, for both food and beverages.

[b] Numbers in parentheses refer to the number of positive records for the hazard, for the considered product (rows).

Table 8: Summary of chemical hazards reported in beverages and frequency of occurrence

Type of product (%; n=67)	Bacterial contaminants (number of records reporting detection) [a]
Fruit juice (n=1, 1%)	Zinc (1)
Soft drinks (n=9, 13%)	Cadmium (2); Chromium (1); Copper (1); Iron (1); Lead (3); Mercury (1)
Zobo (n=3, 4%)	Iron (1); Lead (1); Zinc (1)
Alcoholic drinks (n=7, 10%)	Cadmium (1); Lead (3); aluminium (1); copper (1); iron (1)
Kunun-zaki (n=3, 4%)	Iron (1); Lead (1); Zinc (1)
Water (n=38, 56%)	Arsenic (3); Bromine (3); Cadmium (3); Chromium (3); Copper (1); Iron (2); Lead (8); Manganese (4); Molybdenum (1); Nickel (4); Phosphate (3); Selenium (3)

[a] Numbers in parentheses refer to the number of positive records for the hazard, for the considered product (rows), over a total of 67 positive records on chemical hazards, for both food and beverages.

Preliminary information on frequency of hazard occurrence can be gleaned from the reviewed studies. For example, Karshima *et al.* (65) analyzed 600 milk samples obtained from Kanam, Plateau State and found 52 (8.7%) to be positive for *Salmonella*. The number of positive samples, out of a total of 200 was (by product type): 38 (6.4%) for fresh milk, 9 (1.5%) for Kindirmo, and 5 (0.8%) for nono. Several risk factors for *Salmonella* occurrence included sucking milk directly from the udder, use of stream water to process milk, and failure to wash udder before milking. In a similar study, also in Plateau State, Dafur *et al*. (61) analysed "nono" samples sourced from markets within Mangu (n=300). They found 129 (43%) to be positive for *Escherichia coli*, 49 (16%) for *Staphylococcus aureus*, 15 (5%) for *Pseudomonas aeruginosa*, 30 (10%) for *Salmonella* spp., and 25 (8.3%) for *Shigella* spp. Makut *et al*. (66) analyzed microbial contamination of raw milk, nono, Kindirmo and Manshanu and reported occurrence of *E. coli* (50%), *Staphylococcus aureus* (20%), *Salmonella* (17.5%), and *Streptococcus* spp. (12.5%) to occur. *Saccharomyces cerevisiae* (34%), *Klebsiella* spp. (22%) and *Staphylococcus aureus* (14.64%) were among the pathogens that Aboh and Oladosu (67) isolated from kunun-zaki (n=41) that was fresh and had been sourced from multiple locations in Abuja.

Etang *et al*. (68) investigated the microbiological quality of Kunu drinks produced and sold in Calabar. They reported a total of 40 bacterial and 21 fungal isolates (from a total of 9 samples). The bacterial isolates included *Lactobacillus* spp. (22.5%), *E. coli* (15%), *Staphylococcus aureus* (10%), *Lactobacillus* spp. (22.5%), *Proteus* spp. (7.5%), *Pseudomonas aeruginosa* (7.5%), *Streptococcus* spp. (10%), *Salmonella* spp. (12.5%), and *Bacillus* spp. (15%). Among fungal isolates, *Saccharomyces* spp. (28.5%), *Fusarium* spp. (9.5%), *Aspergillus* spp. (19%), *Penicillium* spp. (19%) and *Rhizopus* spp. (24%) were reported.

Jegede *et al*. (69) analyzed three soft drink and 3 alcoholic drink brands for heavy metal contamination. Alcoholic drinks were found to have higher copper levels than the soft drinks, but levels in both were within the acceptable limits. For lead, the level in soft drinks was 0.18 ± 0.25 mg/L compared to 0. 0.24 ± 0.11mg/L in the alcoholic drink. The levels exceeded the specified limit of 0.01 mg/L. Okareh *et al*. (70) analyzed heavy metal concentration in alcoholic beverages flavoured with herbal extracts. Lead concentration was found to range from 2.13–4.70 mg/L while cadmium ranged from 0.06–0.07 mg/L; the levels were above Codex permissible levels (71).

4. DISCUSSION

4.1 Occurrence of high-burden foodborne disease hazards

Research on food safety in Nigeria has been increasing, evidenced by an increase in scientific publications in the food safety arena between 1990 and 2020, which is in line with global scientific publication trends (72). Recent publications reviewed in this report, however, appear to be focused on only a relatively small number of foodborne hazards across various commodity groups. In addition, low research priority was seemingly given to many hazards estimated to have the greatest burden in the region, and the research focus seems to be on the 'trivial many' rather than the 'vital few' (6).

Within the AFR D region, which includes Nigeria, the top 10 hazards, by DALY burden per 100,000 people, estimated by the WHO-FERG are shown in Box 1. This review disclosed the relatively poor research coverage of those priority hazards within the region. In line with the earlier ILRI review on hazards in food (6), there were no published research on viral foodborne pathogens identified and very little data on foodborne parasitic diseases. The parasitic zoonoses *Taenia solium* is known to cause a large burden of disease (as the etiological agent of neurocysticercosis), yet only one study was identified from Nigeria. This study estimated a 4.4% prevalence in pigs slaughtered in Ibadan state from a sample of 250 pigs (74). The diagnosis was undertaken by visual inspection of the carcass, yet a description of cysts being identified in the subcutaneous fat is not in line with the typical predilection sites of *T. solium* cysticerci and casts doubt on the robustness of this study. These findings suggest further research is warranted on the

Box 1. Top 10 hazards by burden in the AFR D region (WHO FERG, 2015) (2)

(*Mean, 95% confidence intervals*)

- non-typhoidal *Salmonella* (338, CI 94-612)
- *Tenia solium* (170, CI 110-283)
- Enteropathogenic *E. coli* (136, CI 11-329)
- Enterotoxigenic *E. coli* (107, CI 26-245)
- Norovirus (75, CI 6-222)
- *Campylobacter* spp. (71, CI 35-119)
- *Vibrio cholera* (70, CI 2-197)
- *Shigella* spp. (37, CI 0-156)
- *Salmonella typhi* (47, CI 0-169)
- aflatoxin (28, CI 7-78)

occurrence of parasitic foodborne pathogens in Nigeria. In contrast, while the estimated burden from aflatoxin in the region places it within the 'top 10' foodborne hazards, mycotoxins were overrepresented in the literature identified from Nigeria. Further consideration should be given to estimating the relative burden of aflatoxicosis within a local context prior to the commissioning of more studies demonstrating the prevalence of mycotoxins in food products.

For bacterial hazards associated a significant health burden by WHO FERG, only four studies investigated either *Vibrio* spp., *Salmonella* spp., *Shigella* spp., or Shiga-toxigenic *E. coli* 0157:H7 in animal source foods (ASF). Only one study on high-importance microbial pathogens in non-ASF commodities identified *E. coli*, *Salmonella* spp., and *Shigella* spp. in cassava flour (garri) (52). Given that fruits and vegetables, along with ASFs, pose a potential high risk of microbial contamination (15), the lack of evidence for microbial contamination in fruit and vegetables in the Nigerian context is also a key research need.

There were several limitations of the 2010 FERG estimates due to lack of data, particularly regarding chemical hazards. Updated estimates by the Chemical and Toxicants subgroup of FERG found the burden of disease from four heavy metals (arsenic, lead, cadmium, and methylmercury) to be 160 DALYs per 100,000 (95% CI: 50 – 823) in the AFR D region, with lead and methylmercury contributing a burden of 67 (95% CI: 0-573) and 54 (95% CI: 21-146) DALYs/100,000 respectively. These estimates place chemical hazards within the range of the top hazards by burden in this region, although the wide confidence interval reveal the limitations of data informing these estimates (73).

In light of the FERG high estimates of health burden related to heavy metal contamination in food (73), it is notable that only four studies from Nigeria reviewed here considered heavy metals in foodstuffs. Heavy metals exceeding recommended limits (71) were detected in ready-to-eat sausage rolls in Osun state, fish purchased from fishermen in Lagos, and locally grown and imported fruits from Anambra state. In a study in Imo state, soya beans were considered to pose a low risk to consumers from arsenic contamination (53). To address the uncertainty surrounding burden estimates of heavy metal contamination, appropriately designed studies investigating the highest-risk products are needed.

4.2 Polycyclic Aromatic Hydrocarbons (PAHs)

A category of chemical hazards which does not have a burden estimate in the WHO FERG reports, potentially due to the difficulty in disaggregating the environmental and foodborne exposure routes, are polycyclic aromatic hydrocarbons (PAHs). Several PAHs are potent carcinogens and their production is associated with various cooking or processing methods, particularly roasted, grilled, fried, and smoked foods as a by-product of incomplete combustion. Two studies identified in this review assessed PAH levels, and found them above recommended levels in beef sausage rolls from Osun state and samples of grilled or smoked fish and meat from Lagos and Ogun states (75,76). Improving methods of cooking for ready-to-eat foodstuffs would be a step towards mitigating exposure through foods.

4.3 Biological and chemical hazards in ready-to-eat foodstuffs

The literature reviewed in this report indicate the presence of several important biological and chemical hazards, including priority bacterial pathogens, mycotoxins, and carcinogenic chemical compounds associated with ready-to-eat foods, also known as 'street foods'. These foods are particularly popular in urban areas, have cultural, economic, and social relevance and are of importance in LMICs where their low cost make them a staple for many people living in informal settlements where cooking facilities may be lacking.

Developing interventions to reduce biological and chemical hazards in foods sold in a street context (and those likely to be eaten almost immediately) is likely to have large impacts on subsequent disease burden. Therefore, EatSafe is planning to conduct risk modelling, building upon the data available on a selection of ready-to-eat foods, to determine likely risk to consumers and to assist in the design of acceptable, contextually relevant and cost-effective interventions.

4.4 Study limitations and research needs

This report presents findings from an SLR on foodborne hazards in foods and beverages consumed in Nigeria. The study identified numerous relevant publications and associated data. Limitations in the identified evidence are due both the amount and quality of available published studies, and to the SLR searching and filtering approach. Limitations in the current study include:

- strict quality control, which while warranted, may have excluded some useful information;
- unpublished data (e.g. theses) and grey literature were not included;
- several hazards that are known or suspected to be important have not been well reported or characterized in the literature (i.e. absence of evidence is not evidence of absence);
- for several commodities and hazards, the small number of studies hinders the ability to make statements about Nigeria as a whole, in particular in light of the variability in production practices and diets across states;
- the high heterogeneity in methods and approaches hinders the ability to summarize and generalize findings.

As a result, several areas for future research have been identified, including:

- Occurrence and levels of zoonotic parasites, such as *Taenia solium*
- Microbial contamination in fresh fruits and vegetables
- Occurrence and levels of viral foodborne pathogens in all relevant food commodities, in particular animal-sourced foods and fresh fruits and vegetables

- For all studies, concentration levels should be measured in order to provide quantitative information on severity of contamination, not only frequency, and to support the development of quantitative risk analyses to estimate burden.
- Risk ranking, based on burden of FBD for different commodities and hazards, would support the effective prioritization of intervention efforts.

5. CONCLUSIONS

Public health departments need data to base their decisions on disease control, but lack of surveillance systems make this difficult. Allocation of resources for food safety improvement should rely on both estimates of FBD burden, and on hazard characterization in different food commodities. The current review identified hazards of public health importance and synthesized available credible evidence. This information can be used as preliminary input in semi-quantitative or in some cases quantitative approaches to assess risk in selected commodity/hazard pairs. However, very little information on occurrence of the WHO's "high priority" hazards was observed. For instance:

- Evidence on parasitic hazards is lacking in the literature.
- Few studies were found on hazard occurrence in fresh fruits and vegetables, yet these commodities have been found to be important sources of exposure.
- Contamination was reported in several beverages that are commonly consumed in Nigeria, but further research is needed to assess risks associated with their consumption, in absolute terms and relative to foods.

Contamination can arise from the use of contaminated raw materials (which may be of different types), use of contaminated water, as well as poor handling of the final product. Contamination with hazards such as the Escherichia coli, Salmonella typhi etc. is an indication of poor hygiene in the handling of the products.

Hazard measurements are often conducted at one or a limited number of stages along the supply chain. Additional research is needed to map hazard occurrence through the value chains in order to determine critical points that can be targeted for their control.

Overall, a limited but sizeable and growing body of evidence on foodborne and beverage-borne hazards is available in Nigeria. However, the low quality of a large proportion of the screened studies (e.g., 191 out of 418 for beverages), highlights that harmonization and appropriateness of study methodology is a high priority to ensure cost-effective food safety research. In light of major gaps in Nigeria-specific evidence, the WHO FERG regional burden estimates are recommended as a reference to guide risk prioritization (2).

Further analysis of the literature identified through this systematic review, complemented by new data collection, could inform formal risk assessments, which in turn can inform the prioritization and design of interventions to improve food safety in the country.

Box 2. Recommendations for Intervention Design and Future Studies under EatSafe

This systematic review evaluated and synthesized available evidence on the occurrence and levels of hazards in food and beverages consumed in Nigeria. Based on the results of this review, we recommend EatSafe consider the following points in the design of interventions to improve food safety:

- Promisingly, food-safety research appears to be increasing in Nigeria.
- For selected commodities and hazards, available data can be leveraged for semi-quantitative risk assessments; however, significant data gaps exist that need to be filled by new data collection in order to support quantitative burden estimates.
- There is still a strong focus on the 'trivial many' rather than the 'vital few' in the available literature, i.e. hazards responsible for the highest health burden have not received sufficient attention.
- Based on available evidence, beverages should also be included in food safety hazard characterization efforts; while some studies provide evidence on heavy metals, no study on microbial pathogens in beverages was identified.
- In order to estimate the burden of disease via risk assessment, data on both prevalence and concentration of hazards, as well as information on supply chain and consumption practices, are needed. Prevalence alone does not provide sufficient information to estimate risk. Hence, studies measuring concentration should be encouraged.
- Targeted, risk-based, novel data collection on hazard occurrence and levels is recommended to support quantitative risk estimates and risk ranking in the Nigerian context, which is needed to justify interventions (in tandem with disease surveillance data). Microbial pathogens in ASF and fruits/vegetables, as well as beverages, constitute major gaps.
- The EatSafe program should be guided by best evidence on the relative risk from different hazards and commodities, to guide the choice of hazard and value chains to focus research interventions to maximize the public health impact. Major gaps in Nigeria-specific evidence was identified in this review, and analysis of epidemiological data was not in scope. Pending novel data collection, the WHO FERG burden estimates are recommended as the best available guidance.

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APPENDIX 1. *Protocol used in SLR for foods*

The protocol had been developed by ILRI for use in a previous SLR in which three countries including Nigeria were involved (6). It was used to provide additional data for Nigeria (for the period 2017-2020).

Aspect of the protocol	Description
Rationale	A study to identify the most relevant FBD in three target countries (Ethiopia, Burkina Faso and Nigeria) according to the incidence in humans, health burden and prevalence in foods. The aim is to then identify the food value chains of relevance to subsequently undertake a more rigorous assessment of food safety performance systems.
Aim	To identify the most relevant FB hazards associated with water (for drinking or food preparation), vegetables, ASF and other human food products in all age groups in three target countries (Ethiopia, Burkina Faso and Nigeria) according to the incidence in humans, health burden and prevalence in the foods
Research question	What is the incidence of FBDs in Ethiopia, Burkina Faso and Nigeria What is the health burden (DALYs, % of symptomatic cases; severity; mortality; hospitalization; duration of illness; long-term sequelae) associated with those FBD in Ethiopia, Burkina Faso and Nigeria What is the prevalence of foodborne hazards in water, vegetables, ASF and other food products in Ethiopia, Burkina Faso and Nigeria
Population	Individuals, all ages, both genders, in Ethiopia and Burkina Faso; all types of human food products.
Intervention	na
Control	na
Outcome	Incidence (annual n. of clinical cases, annual n. of deaths) Health burden (DALYs; % of symptomatic cases; severity; mortality; hospitalization; duration of illness; long-term sequelae) Prevalence (% of infected/contaminated products) – with prioritized list of FB hazards in each country
Setting	Ethiopia, Burkina Faso and **Nigeria**
Protocol registration	Not finalized but being pursued
Eligibility criteria	**Inclusion criteria** Type of studies: observational studies, secondary data analysis, (literature) reviews Time limits: Studies published from 2017-2020 Language – English (all countries), French (Burkina Faso) **Exclusion criteria** Studies focusing exclusively on non-foodborne illness/hazards Experimental laboratory studies

Eligibility criteria	Antimicrobial RESISTANCE studies (we DO include antimicrobial RESIDUES) If the population is outside Ethiopia and Burkina Faso Studies not reporting information on FB incidence, health burden, prevalence in food products (i.e. studies looking at prevalence of hazards at primary production on targets that are not food *per se*: i.e. faeces from animals, serology from animals, or carriage in vectors)
Information sources	6 Online databases: PubMed, CabDirect, Google scholar, Food Safety and Technology Abstracts and AJOL consider [depending on what was accessible at the time of the review]
Search	See separate description
Study selection	Observational studies, secondary data analysis, (literature) reviews
Data collection process	TITLE/ABSTRACT • Download of titles/abstracts and removal of duplicates • Independent double screening of title/abstract (inclusion/exclusion criteria) • Discussion to reach agreement or third reviewer to review articles considered relevant by only one reviewer • Selection of articles considered relevant by at least 2 reviewers FULL PUBLICATIONS • Download of full publications • Full paper single review (inclusion/exclusion criteria); • Full paper single review (quality criteria) • 10% of publications to be reviewed by all reviewers and data extracted compared. DATA EXTRACTION • Standardized data extraction file *Single data extraction*
Assessment of bias of single studies (quality criteria)	Follow Cochrane “assessment of bias” http://handbook.cochrane.org/chapter_8/8_assessing_risk_of_bias_in_included_studies.htm

APPENDIX 2. *Syntaxes used in SLR for foods*

Database	Key words / syntaxes
PubMed	(foodborne OR "food borne" OR food-borne OR "food safety" OR "food related" OR "food associated" OR "food derived" OR "food* illness" OR "food* disease*" OR "food* intoxica*" OR "food pathogen" OR "food* poison*" OR "food* microb*" OR "food* vir*" OR "food parasit*" OR "food* toxin") AND (Nigeria*))
CAB Direct	(title: (foodborne OR "food safety" OR "food borne" OR "food related" OR "food associated" OR "food derived" OR "food* illness" OR "food* disease*" OR "food* intoxica*" OR "food pathogen" OR "food* poison*" OR "food* microb*" OR "food* vir*" OR "food parasit*" OR "food* toxin") OR ab: (foodborne OR "food safety" OR "food borne" OR "food related" OR "food associated" OR "food derived" OR "food* illness" OR "food* disease*" OR "food* intoxica*" OR "food pathogen" OR "food* poison*" OR "food* microb*" OR "food* vir*" OR "food parasit*" OR "food* toxin")) AND (title: (Nigeria *) OR ab: (Nigeria *))yr:[2017 TO 2019]

APPENDIX 3. *Protocol used in SLR for Beverages*

Aspect of the protocol	Detailed description
Rationale	This is a study on occurrence in Nigeria in beverages in Nigeria. It aims to 1) identify the priority hazards 2) attribute these to their specific sources (or value chains of relevance considering all ingredients), and 3) use the findings to inform the choice of interventions.
Aim	To identify biological and chemical hazards associated with beverage consumption in Nigeria (according to prevalence within beverages and incidence and health burden in humans).
Research question	What hazards have been documented to be associated with beverage consumption in Nigeria? Where data are available, to document; The prevalence of documented hazards in beverages consumed in Nigeria The spatial distribution of these hazards The health burden (DALYs, % of symptomatic cases; severity; mortality; hospitalization; duration of illness; long-term sequelae) associated with beverage-associated hazards in Nigeria
Population	all beverages consumed in Nigeria
Intervention	n/a
Control	n/a
Outcome	Map of beverage-associated hazards reported in Nigeria Prevalence (% of infected/contaminated products) Incidence (annual n. of clinical cases, annual n. of deaths resulting from beverage- associated hazards) Health burden (DALYs; % of symptomatic cases; severity; mortality; hospitalization; duration of illness; long-term sequelae) Produce a prioritized list of beverage-associated hazards in Nigeria
Setting	Nigeria
Protocol registration	Done in PROSPERO
Eligibility criteria	Inclusion criteria Type of studies: observational studies, secondary data analysis, (literature) reviews Time limits: Studies published from 2000 to (date of search) Language – English (mainly)

Eligibility criteria	Exclusion criteria Studies not considering biological or chemical hazards associated with beverages Studies on water quality/safety not associated with drinking water If the population is outside Nigeria Experimental laboratory studies Studies that exclusively focus on non-beverage associated illness/hazards Antimicrobial resistance studies (we DO include antimicrobial RESIDUES) Studies not reporting information on beverage-associated hazard presence, prevalence, incidence or health burden (i.e. studies looking at prevalence of hazards at primary production on targets that are not food per se: i.e. faeces from animals, serology from animals, or carriage in vectors)
Information sources	3 Online databases: The two main databases will be PubMed and ScienceDirect. Google scholar Will be a complementary database.
Search	Refer to table 1 below
Study selection	Observational studies, secondary data analysis, (literature) reviews
Data collection process	TITLE/ABSTRACT Download of titles/abstracts and removal of duplicates Independent double screening of title/abstract (inclusion/exclusion criteria) (reviewer 1 and 2). Screening will be done using the Rayyan QCRI software https://rayyan.qcri.org/welcome. The tool also allows for identification and removal of duplicates. Discussion to reach agreement (reviewer 1 and 2) or review of articles considered relevant by only one reviewer (by reviewer 3) Selection of articles considered relevant by at least 2 of the reviewers Reviewer 3 and 4 will monitor the whole review process on Rayyan. FULL PUBLICATIONS Download of full publications (reviewer 1 and 2) Full paper double review (inclusion/exclusion criteria) (reviewer 1 and 2) using the Rayyan QCRI software. 5% of included and excluded publications will be reviewed by reviewer 3 and 4 Any discordance in classification to be reviewed by reviewer 3 and 4 Full paper single review (quality criteria) by reviewer 1 and 2. 10% of publications to be reviewed by all reviewers and data extracted compared. DATA EXTRACTION – reviewers 1 and 2 overseen by 3 and 4 Standardized data extraction file Single data extraction
Assessment of bias	Follow Cochrane “assessment of bias” http://handbook.cochrane.org/chapter_8/8_assessing_risk_of_bias_in_included_studies.htm

APPENDIX 4. *Syntaxes used in SLR for beverages [PubMed]*

Key words / syntaxes
(milk or “drinking water” or “potable water” or drink* or beverage* or juice* or soymilk or soyamilk or "kunun-zaki" or kindirmo or kunlun or kunu or soborodo or nono or zobo or kurumaya or ogwo or isaya or kunu or "non-alcoholic" or "nonalcoholic” or alcohol*) AND (safety OR borne OR related OR associated OR illness OR disease OR pathogen OR poison* OR microb* OR virus* OR parasit* OR Toxin OR toxicant OR metabolite OR chemical OR intoxica*) AND Nigeria* NOT “breast milk” NOT "breast-milk" NOT "breastmilk"

APPENDIX 5. *Syntaxes used in SLR for beverages [Science Direct]*

Key words / syntaxes	Search output
Beverage AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	2072
Milk AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	4252
“Drinking water” AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	2806
Drink AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	5436
“Potable water”AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	638
Juice AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	1883
Alcohol AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	6155
Nonalcoholic AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	179
Soymilk AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	74
Kunun-zaki AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	30
Kunu AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	38
Zobo AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	18
kunlun AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	16
Nono AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	70
Ogwo AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	4
Soborodo AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	3

Kurumaya AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	1
Isaya AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	3
Kindirmo AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	3
Soyamilk AND (safety OR disease OR pathogen OR poison OR microbe OR Toxin OR chemical) AND Nigeria	1

APPENDIX 6. *Syntaxes used in SLR for beverages [Google Scholar]*

Google Scholar Syntax	Number of hits	Number extracted
Nigeria AND milk safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin|toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	56200	300
Nigeria AND drinking water safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	65,600	300
Nigeria AND potable water safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	19,900	300
Nigeria AND drink safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	28700	300
Nigeria AND beverage safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	18600	300
Nigeria AND juice safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	19400	300
Nigeria AND soy milk safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	8770	300
Nigeria AND soya milk safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	18500	300
Nigeria AND "kunun-zaki"safety|borne|related|associated|illness|disease|pathogen|poison|micro	566	300

be|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"		
Nigeria AND kindirmo safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	65	93
Nigeria AND kunlun safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	352	300
Nigeria AND kunu safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	1030	300
Nigeria AND soborodo safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	220	232
Nigeria AND nono safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	18000	300
Nigeria AND zobo safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	850	300
Nigeria AND kurumaya safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	7	7
Nigeria AND ogwo safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	1250	300
Nigeria AND isaya safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	258	299
Nigeria AND non-alcoholic safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	6980	300
Nigeria AND alcohol safety|borne|related|associated|illness|disease|pathogen|poison|microbe|virus|parasite|toxin |toxicant|metabolite|chemical|intoxication –"breast milk" –"human milk"	103,000	300

APPENDIX 7. *Study summary table [food]*

Lead author	Location	Sample type	Hazard type	Hazard name
Abass et al. (51)	Several	Cassava	Biological	Aflatoxins
Adesetan et al. (37)	Ogun	Retail foods (rice, smoked meat and fish, vegetables)	Biological	*Bacillus Cereus*
Adesokan and Adeoye (74)	Ibadan (Oyo state)	Slaughter pigs	Biological	*Taenia solium*
Adetunji et al. (77)	Lagos, Ogun	Cashew nuts; groundnuts	Biological	Aflatoxins
Adikwu et al. (29)	Markudi (Benue state)	Pig carcasses	Biological	*Staphylococcal aureus*
Agbaje et al. (31)	Kaduna	Chicken carcasses	Biological	*Salmonella spp.*
Beshiru et a. (35)	Delta, Edo	Ready to eat shrimps	Biological	*Salmonella spp.*
Beshiru and Igbinosa (36)	Delta, Edo	Ready to eat shrimps	Biological	*Vibrio spp.*
Chukwu et al. (78)	Lagos	Food, patient samples	Biological	*Clostridia spp.*
Ezekiel et al. (79)	Ogun	Urinary AFM1 exposure marker in humans (rural and urban populations)	Biological	Mycotoxins
Ezeonyejiaku and Obiakor (80)	Akwa, (Anambra state)	Fruits	Chemicals	Arsenic, mercury, lead, copper
Fapohunda et al. (81)	Abuja (6 zones)	Sesame, soybeans	Biological	Mycotoxins
Ezekiel et al. (82)	Kaduna, Kasarawa	Cooked/ non-cooked (maize flour, grain; others - rice, cassava, yam	Biological	Mycotoxins
Innocent et al. (83)	Benue -2 markets	Garri – cassava ready to eat food	Biological, chemical	Multiple bacteria; quality indicators; heavy metals
Igbinosa and Beshiru (84)	Delta	Sea food	Biological	*Enterococcus spp.*
Liverpool-Tasie et al. (47)	Oyo	Maize – farm, market, processed	Biological	Mycotoxins

Kelechi et al (85)	Imo	Beans (sold in closed and open containers)	Chemical	Arsenic
Nwosu et al. (86)	Imo	Bean Seeds	Chemical	Arsenic
Ogugua et al. (87)	Oyo, Lagos	Milk	Biological	Brucellosis
Okoli et al. (33)	Enugu	Ready to eat meat samples (roasted/spiced)	Biological	Staphylococcus spp.
Odetokun et al. (30)	Oyo, Kwara	Slaughter animals, abattoir workers	Biological	*Staphylococcal aureus*
Oguguah and Ikegwu (41)	Lagos	Fish – bought from fishermen	Chemical	Heavy metals
Ojuri et al. (49)	Lagos, Ogun	Cereal /nut based complementary foods	Biological	Mycotoxins
Olalemi (32)	Akure, Ondo State	African catfish	Biological	Multiple
Olatoye et al. (88)	Oyo, Lagos	Poultry eggs	Chemical	Antimicrobial residues (gentamicin)
Oranusi et al. (38)	Lagos, Ogun	Yam, plantain, fish, meat	Biological Chemical	Multiple pathogens, Polycyclic Aromatic Hydrocarbons (PAH) and Heterocyclic Amines (HCA)
Oyekunle et al. (75)	Ile-Ife, Osun	Beef sausages	Chemicals	polycyclic aromatic hydrocarbons; heavy metals
Oyedele et al. (50)	Multiple areas	Groundnuts	Biological	Mycotoxins
Sowemimo et al. (89) (89)	Osun	Pre-school children	Biological	*Toxoplasma gondii*
Yakubu et al (34)	Sokoto Metropolis	Milk – farm, retail	Biological	*Shiga Toxigenic Escherichia coli O157:H7*

APPENDIX 8. *Study summary table [beverages]*

Lead author	Location	Beverage type	Hazard type	Hazard name
Ajayi (90)	Ibadan	water	Biological	multiple
Stella (91)	Delta	milk	Biological	antimicrobial residues
Chukwu (92)	Lagos	milk	Biological	Clostridium
Aboh (93)	Kaduna	water	Biological	multiple
Agada (94)	Oyo	milk	Biological	Mycobacterium
Ivbade (95)	Ogun	milk	Biological	Escherichia coli
(96) Cadmus (96)	Niger	milk	Biological	Mycobacterium
Adesina (97)	Ekiti	milk	Biological	multiple
Enem (98)	FCT	milk	Biological	Escherichia coli
Yarubu (34)	Sokoto	milk	Biological	Escherichia coli
Onioshun (99)	Kaduna	milk	Biological	Salmonella
Maduabuchi (100)	Not specific	canned, non-canned beverages	Chemical	multiple
Enurah (101)	multiple	milk	Biological	Listeria
Dayok (102)	Plateau	milk	Biological	multiple
Olufemi (103)	Abeokuta	milk	Biological	Staphylococcus
Esomonu (104)	Imo	water	Biological	multiple
Isikwue (105)	Bauchi	water	Biological	quality indicators
Yahaya (106)	Lagos	water	Chemical	multiple
Cynthia (107)	multiple	Burukutu; pito	Biological	mycotoxins
Iroha (108)	Ebonyi	Zobo	Biological	multiple
Shittu (109)	Abeokuta	water	Biological	multiple
Ikpoh (110)	Kaduna	milk, nono	Biological	Staphylococcus
Omolade (111)	Lagos	water	Biological	parasites
Aliyu (112)	Nasarawa	Nono; milk; kindirmo	Biological	Staphylococcus
Gyar (113)	Niger	Kunun-zaki	Biological	multiple
Onwughara (114)	Abia	water	Biological	quality indicators
Enabulele (115)	FCT	nunu	Biological	Escherichia coli
Olufunke (116)	Osun	milk	Biological	Salmonella
Eruola (117)	Ogun	water	Chemical	multiple
Duruibe (118)	Ebonyi	water	Chemical	multiple
Oluwaseun (119)	Ogun	water	Biological	quality indicators
Enabulele (120)	Multiple	nono	Biological	Escherichia coli
Bala (121)	Niger	water	Biological	multiple
Iroegbu (122)	Enugu	water	Biological	quality indicators
Karshima (65)	Plateau	milk, kindirmo, nono	Biological	Salmonella
Ogodo (123)	multiple	Fruit juice	Biological	multiple
Awah (124)	Anambra	milk	Biological	multiple
Popoola (125)	Kano	Akamu	Biological	quality indicators
Onilude (126)	Oyo	water	Biological	multiple

Raji (127)	Sokoto	water	Chemical	multiple
Udota (128)	Ibom	alcoholic	Chemical	multiple
Okeri(129)	Edo	Fruit juice, water	Chemical	multiple
Egwaikhinde (130)	Kaduna	nono	Biological	multiple
Mbaeyi-Nwaoha (131)	Enugu	water, zobo, milk	Biological	Escherichia coli
Aboh (67)	FCT	kunun-zaki	Biological	multiple
Yakubu (132)	Sokoto	milk	Biological	Listeria
Adefemi (133)	Ondo	water	Chemical	multiple
Oboh (134)	Ondo	water	Chemical	multiple
Abua (135)	Cross River	water	Chemical	multiple
Magomya (136)	Kaduna	Soft drink	Chemical	multiple
Nduka (137)	Delta	water	Chemical	nitrate
Ani (138)	multiple	Soft drink; water	Chemical	Fluoride
Godwill (139)	Enugu	Soft drink	Chemical	multiple
Ekwunife (140)	Anambra	water	Biological	parasites
Orisakwe (141)	multiple	water	Chemical	multiple
Atanda (142)	Ogun	milk	Biological	mycotoxins
Osopale (143)	multiple	Fruit juice	Biological	Alicyclobacillus
Olaoye (144)	multiple	water	Biological	multiple
Ngwai (145)	Bayelsa	water	Biological	quality indicators
Nwosu (146)	Nasarawa	milk	Biological	multiple
Ugboma (147)	Sokoto	water	Biological	Campylobacter
Ekwunife (148)	Enugu	Local drinks - Soya, Kunun-zaki, Zobo	Biological	parasites
Kelechi (85)	Abia	kunun-zaki	Biological	Escherichia coli
Fowoyo (149)	multiple	Kindirmo; nono; kunun-zaki	Biological	Staphylococcus
Odeleye (150)	Oyo	water	Biological	multiple
Yabaya (151)	Kaduna	milk	Biological	multiple
Oluwafemi (152)	Oyo	water	Biological	multiple
Bakare-Odunola (153)	Kaduna	Zobo; Kunun-zaki	Chemical	multiple
Dafur (61)	Plateau	Nono	Biological	multiple
Adetunde (154)	Oyo	water	Biological	quality indicators
Ikpoh (110)	Cross River	kunun-zaki	Biological	multiple
Ofukwu (155)	Benue	milk, nono	Biological	multiple
Umaru (156)	Kaduna	milk, kindirmo	Biological	Staphylococcus
Mailafia (157)	FCT	milk	Biological	multiple
Usman (158)	Kaduna	milk, Nono	Biological	Staphylococcus
Akinyemi (159)	Lagos	water	Biological	Salmonella
Makut (66)	Nasarawa	milk, nono, kindirmo	Biological	multiple
Okareh (70)	Oyo	alcoholic	Chemical	multiple

Orewole (160)	Osun	water	Chemical	Lead
Etang (68)	Cross River	kunun-zaki	Biological	multiple
Ugochukwu (161)	Kaduna	water	Biological	multiple