Prevalence of multi-drug resistant bacteria associated with foods and drinks in Nigeria (2015-2020): A systematic review

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Abstract
Foods are essential vehicles in human exposure to antibiotic resistant bacteria which serve as reservoirs for resistance genes and a rising food safety concern. Antimicrobial resistance, including multi-drug resistance (MDR), is an increasing problem globally and poses a serious concern to human health. This study was designed to synthesize data regarding the prevalence of MDR bacteria associated with foods and drinks sold within Nigeria in order to contribute to the existing findings in this area. A comprehensive literature search on the prevalence of multi-drug resistant bacteria associated with foods and drinks in Nigeria from 2015 to 2020 was conducted using three databases; PubMed, Science Direct and Scopus. Articles were screened and selected, 26 out of 82 articles were used for the qualitative data synthesis. Of the total of one thousand three hundred and twenty-six MDR bacteria reportedly isolated in all twenty-six articles, the highest prevalence (660) was observed in drinks, including water, while the lowest (20) was observed in the article which combined processing if food safety standards are not correctly applied (Mesbah et al., 2017). Food-borne diseases caused by resistant organisms are one of the most important public health problems as they contribute to the risk of development of antibiotic resistance in the food production chain (Hehempour-Baltork et al., 2019). Apart from pathogenic bacteria causing food-borne diseases, foods that are raw or not processed following standard procedures can introduce several antibiotic-resistant bacteria (ARB) to consumers (Gekemidis et al., 2018). Antibiotic resistance, though harbored in non-pathogenic bacteria, can potentially be spread through horizontal gene transfer to other species including opportunistic pathogens that are present in the environment or after consumption of ARB-contaminated foods. When ARB-contaminated foods are consumed, the spread of antibiotic resistant genes may affect the gut microbiome thereby contributing to the pool of antibiotic-resistance genes (ARG) in the human gut (Gekemidis et al., 2018). MDR bacteria have been defined as bacteria that are resistant to at least one antimicrobial agent present in three or more antimicrobial classes (Sweeny et al., 2018). There has been an increase in drug resistance in pathogens isolated from food for human consumption with species of Escherichia coli and Salmonella enterica being considered among the most important pathogens due to their ability to effect zoonotic transfer of resistant genes (Canton et al., 2018; Maneilla-Becerra et al., 2019). However, other pathogens, such as Vibrio spp., some species of Aeromonas, spores of Clostridium botulinum type F, and Campylobacter; have been linked to food-borne diseases in humans who have consumed seafood or other animal foods (Maneilla-Becerra et al., 2019). Some other resistant bacteria associated with foods include Staphylococcus aureus, Listeria spp., and Shigella spp. (Maneilla-Becerra et al., 2019)

This study was therefore designed to synthesize data (2015-2020) regarding the prevalence of MDR bacteria associated with foods and drinks sold within Nigeria in order to contribute to the existing findings in this area.
multi-drug resistance; antibiotic resistant bacteria in foods; antibiotic resistant bacteria in drinks; multi-drug resistant bacteria in foods and multi-drug resistant bacteria in drinks. Articles published in English between 2015 and 2020 that observed bacteria isolated from drinks including juices, water as well as soft drinks which showed resistance to at least one agent in three or more antimicrobial classes were considered for the screening process.

Study selection

Studies included in this review were selected based on their alignment with the search terms earlier reported. Full length research papers of studies conducted within Nigeria were screened according to the inclusion and exclusion criteria defined below.

Inclusion criteria

Inclusion criteria were research articles with cross-sectional designs that were carried out in Nigeria and published in English which reported the prevalence of multi-drug resistant bacteria associated with foods and drinks within the study period. The data synthesis focused only on articles whose full text were freely available online.

Exclusion criteria

Studies whose full texts were inaccessible were excluded as their quality could not be assessed as well as studies that were not carried out between 2015 and 2020. Abstracts, conference proceedings, and review articles and letters to editors were also excluded. Full length articles that did not have direct links with the inclusion criteria above were not included in this systematic review.

Data extraction

Relevant data were extracted from each of the full-text articles into Microsoft Excel. Data extracted included first author’s name, year of sample collection, sampling point, type of samples collected, number of samples collected, class of samples collected, antibiotics used, isolated bacteria, method of antibiotic sensitivity testing, bacterial species isolated, number of antibiotic resistant bacteria, number of multi-drug resistant bacteria, specific antibiotics tested for resistance and percentage of multi-drug resistant bacteria. All data were analyzed and presented in the form of a flowchart, charts, tables, and figures.

Results

Antibiotic resistance

The search term ‘antibiotic resistance’ resulted in a total of one hundred and forty-eight thousand, eight hundred and eighty-three (148,883) articles which comprised research articles, articles published within the study period and generally articles covered within the inclusion criteria for this search with Scopus hosting the largest number of articles (58,879) related to this search term (Table 2).

Multi-drug resistance

The search term ‘multi-drug-resistance’ resulted in a total of forty-seven thousand and sixty-one (47,061) articles which comprised research articles, articles published within the study period covered in this research and generally articles which matched the inclusion criteria for this search with Science direct hosting the largest number of articles (58,879) related to this search term (Table 2).

Multi-drug resistant bacteria in foods in Nigeria

The search term ‘multi-drug-resistant bacteria in foods in Nigeria’ resulted in a total of three hundred and eleven (311) articles which comprised research articles, articles published within the study period covered in this research and generally articles which matched the inclusion criteria for this search with Science direct hosting the largest number of articles (210) related to this search term (Table 2).

Table 1. Search terms used for databases.

| S/N | *Search terms          |
|-----|------------------------|
| 1   | Antibiotic resistance  |
| 2   | Multi-drug resistance  |
| 3   | Antibiotic resistant bacteria in foods in Nigeria |
| 4   | Antibiotic resistant bacteria in drinks in Nigeria |
| 5   | Multi-drug resistant bacteria in foods in Nigeria |
| 6   | Multi-drug resistant bacteria in drinks in Nigeria |
| 7   | 3 or 4                |
| 8   | 5 or 6                |
| 9   | 7 and 8               |

*Search terms were repeated in the same pattern in all three databases employed for this study.

Table 2. Search result for each search item in Scopus, Science Direct and PubMed.

| Search term                  | Scopus       | Science Direct | PubMed       | Total       |
|------------------------------|--------------|----------------|--------------|-------------|
| AR                           | 56879        | 46904          | 45100        | 148883      |
| MDR                          | 4053         | 21662          | 21346        | 47061       |
| ARB in foods in Nigeria      | 32           | 210            | 69           | 311         |
| ARB in drinks in Nigeria     | 0            | 39             | 8            | 47          |
| MDRB in foods in Nigeria     | 84           | 58             | 11           | 153         |
| MDRB in drinks in Nigeria    | 4            | 20             | 3            | 27          |
| 3 or 4                       | 32           | 217            | 75           | 324         |
| 5 or 6                       | 84           | 63             | 13           | 160         |
| 7 and 8                      | 17           | 55             | 10           | 82          |

AR: Antibiotic resistance, MDR: Multi-drug resistant, ARB: Antibiotic resistant bacteria, MDRB: Multi-drug resistant bacteria, 3-8 (Refer to Table 1).
Multi-drug resistant bacteria in drinks in Nigeria

The search term ‘multidrug-resistant bacteria in drinks in Nigeria’ resulted in a total of twenty-seven (27) articles which comprised research articles, articles published within the period covered in this research and generally articles which matched the inclusion criteria for this search with Science direct hosting the largest number of articles (20) related to this search term (Table 2).

Data extraction

After careful searches of databases using the combined search terms in item 9 of Table 1, twenty-six out of a total of eighty-two (84) related to this search term (Table 2).

Table 3. Frequency of MDR bacteria in foods and drinks.

| MDR bacteria       | Frequency | Total no. of isolates | Number of MDR bacteria | % MDR Bacteria |
|--------------------|-----------|-----------------------|-------------------------|----------------|
| Escherichia sp.    | 10        | 860                   | 272                     | 31.6           |
| Staphylococcus sp. | 9         | 286                   | 131                     | 45.8           |
| Salmonella sp.     | 7         | 158                   | 135                     | 85.4           |
| Bacillus sp.       | 5         | 90                    | 14                      | 15.6           |
| Pseudomonas sp.    | 4         | 441                   | 41                      | 9.3            |
| Shigella sp.       | 3         | 18                    | 6                       | 33.3           |
| Proteus sp.        | 3         | 91                    | 6                       | 6.6            |
| Klebsiella sp.     | 2         | 28                    | NA                      | –              |
| Enterobacter sp.   | 2         | 51                    | 18                      | 35.3           |
| Clostridium sp.    | 1         | NA                    | NA                      | –              |
| Alcaligenes sp.    | 1         | NA                    | NA                      | –              |
| Lactobacillus sp.  | 1         | NA                    | NA                      | –              |
| Plesiomonas sp.    | 1         | 66                    | 66                      | 100            |
| Serratia sp.       | 1         | 12                    | NA                      | –              |
| Vibrio sp.         | 1         | NA                    | NA                      | –              |
| Photobacterium sp. | 1         | NA                    | NA                      | –              |
| Campylobacter sp.  | 1         | NA                    | NA                      | –              |
| Neisseria sp.      | 1         | NA                    | NA                      | –              |
| Propionibacterium sp. | 1   | NA                    | NA                      | –              |
| Amycolatopsis sp.  | 1         | NA                    | NA                      | –              |
| Eubacterium sp.    | 1         | NA                    | NA                      | –              |
| Chromobacterium sp. | 1       | NA                    | NA                      | –              |
| Tropheryma sp.     | 1         | NA                    | NA                      | –              |
| Enterococcus sp.   | 1         | 268                   | 129                     | 48             |
| Total              | 61        | 2369                  | 818                     | 34.5           |

NA, Numbers of specific genera of the MDR bacteria were not specified in the searched articles.
objectives of this research (Figure 1). Amongst the twenty-six articles searched, *Escherichia sp.* had the most frequency of occurrence, appearing as MDR bacteria in ten out of the twenty-six articles while *Clostridium sp.*, *Alcaligenes sp.*, *Lactobacillus sp.*, *Plesiomonas sp.*, *Serratia sp.*, *Vibrio sp.*, *Photobacterium sp.*, *Campylobacter sp.*, *Neisseria sp.*, *Propionibacterium sp.*, *Amycolatopsis sp.*, *Eubacterium sp.*, *Chromobacterium sp.*, *Tropheryma sp.*, *Enterococcus sp.* had the least occurrence recorded only in one article (Tables 3 and 4). Of the eight hundred and sixty *Escherichia sp.* isolated from various food and drink samples in all twenty-six articles, two hundred and seventy-two (272) were multi-drug resistant, giving a percentage prevalence of 31.6% MDR bacteria. *Salmonella sp.*, although reported as MDR in only seven of the twenty-six articles had the highest prevalence of 135 MDR out of 158 total isolated (85.4%) while *Shigella sp.* and *Proteus sp.* had an occurrence of six (6) MDR bacteria out of 18 and 91 respectively amounting to percentage of 6.7 and 33.3 respectively in both isolates (Table 3). When observed according to different geopolitical zones of Nigeria, in all cases of MDR bacteria, the Southwest had the most occurrence with the exception of *Staphylococcus sp* and *Salmonella sp* whereas the South-South had the highest occurrence and an equal distribution for Southwest and North central respectively (Table 5). Based on major food groups, of the twenty-six articles, fourteen (14) of them reported isolating MDR bacteria from proteins, eight (8) from drinks, two (2) from vegetables, one (1) from carbohydrates, another one (1) reported isolating from both proteins and vegetables (Figure 2, Table 4). Of the total one thousand three hundred and twenty-six MDR bacteria reportedly isolated in all twenty-six articles included in this search, the highest (660) was observed in drinks, including water, while the least (20) was observed in the article which combined results for both protein and vegetables (Figure 3). In all sixty-five antibiotics screened in the twenty-six articles, one hundred percent (100%) resistance was observed in Methycillin (MET), Penicillin (PEN), Augmentin (AUG), Cefprozil (CPR), Ticarcillin (TIC), Cefazolin (CFZ), Ampicillin-Sulbactam (SAM), Enrofloxacin (ENR), Levofloxacin (LVX), Doxycycline (DOX), Sulphamethoxazole (SMX), Florfenicol (FLO), Cephalothin (CEF), Pefloxacin (PFX), Sparfloxacin (SPX), Ampiclox (AX), Carbenicillin (CAR), Metronidazole (MTX), Clarithromycin (CLR), Aztreonam (ATM), Ticarcillin-Clavulanic acid (TIM), Piperacillin (PIP) and Ceftiofur (CTF). However, six out of the total twenty-six articles reported one hundred percent resistance to penicillin (Table 6).

**Discussion**

**Multi-drug resistant (MDR) bacteria isolates**

From this systematic review, of all the MDR bacteria reported to be associated with foods and drinks, those with high percentages of occurrence include *Escherichia sp.*, *Staphylococcus sp.*, *Salmonella sp.*, *Bacillus sp.*, *Pseudomonas sp.*, *Shigella sp.*, *Proteus sp.*, *Klebsiella sp.*, *Enterobacter sp.*, with *E. coli* showing the highest case of occurrence. In 2015, Adenipekun et al. (2015) reported isolating 211 *E. coli* from cattle, chicken and swine out of which 26 were multi-drug resistant to tetracycline (124/211;58.8%), trimethoprim/sulfamethoxazole (84/211;39.8%), and ampicillin (72/211;34.1%). Adesoji et al. (2019a) also reported the presence of MDR bacteria which were resistant to Ceftazidime, Cefuroxime, Gentamicine, Ciprofloxacin, Ofloxacin, Amoxyccillin clavulanate, Nitrofurantoin, Ampicillin, Erythromycin, Cloxacillin (5μg),
| Authors                          | Food type                          | Type of antibiotics used | Method of testing | MDR bacteria/resistotypes                  | Resistance pattern                                                                 |
|---------------------------------|------------------------------------|--------------------------|-------------------|-------------------------------------------|------------------------------------------------------------------------------------|
| Igbinosa et al., 2016a          | Beef, pork, chicken                | MET, CXC, PEN, AMX, ERY, GEN, KAN, CLI, VAN, CHL, SXI | Disc diffusion    | Staphylococcus sp.                      | Resistant to $\geq 1$ antimicrobial agent in $\geq 3$ classes of antimicrobial agents |
| Musa et al., 2020               | Raw meat                           | CHL, CRO, AMP, TET, NAT, ERY, CIP, COT | Disc diffusion    | Salmonella sp.                          | Resistant to $> 2$ class of antimicrobial agent                                    |
| Ushe et al., 2017               | Beef, chicken                      | AMX, NIT, GEN, NAT, OFX, AMC, TET, SXI | Disc diffusion    | $S. enteritidis, S. typhimurium$         | Resistant to $\geq 5$ antibiotics                                                  |
| Hänni et al., 2016              | Chicken, meat, Egg Poultry egg contents | CRO, PEN, GEN, AMX, NAT, TET, AMC, SXI, OFX, CTX, TOB, CAZ, IPM, ETP, NAT | Disc diffusion    | Salmonella sp.                          | Resistant to greater than 50% of antibiotics tests                                 |
| Kwoji et al., 2019              | Poultry                            | FOX, ERY, VAN, NAT, TET, COT, STR, CHL, CIP | Disc diffusion    | Staphylococcus aureus                   | Resistant to $> 2$ class of antimicrobial agent                                    |
| Aderoju et al., 2019a           | Suya, Smoked fish                  | CAZ, GEN, OFX, AUG, CXM, NIT, AMP, ERY, CPR, CXC, CRO | Disc diffusion    | $S. aureus, E. coli, Pseudomonas sp.$    | Resistant to $> 2$ class of antimicrobial agent                                    |
| Otoye et al., 2019              | Milk, cheese, beef, chicken, yogurt | AMP, TIC, CFZ, LEX, CXM, FOX, CAZ, CTX, IPM, MEM, AMC, SAM, TET, AMK, KAN, GEN, TOB, SPT, CIP, ENR, LVX, DOX, TET, SMX, SXI, TMP, CST, CHL | Disc diffusion    | $E. coli$ (biofilm forming)             | Resistant to $> 2$ classes of antimicrobial agent                                    |
| Amanze et al., 2016             | Suya                               | AMX, NAT, TET, VAN, GEN, STR, CHL, ERY, ERY, CXM, NIT, CIP | Disc diffusion    | $S. aureus, Bacillus sp., S. typh and $E. coli$ | Resistant to at least three antibiotics                                             |
| Ahmed et al., 2019              | Poultry                            | TET, STR, NAT, NEO, CTX, CAZ, CHL, FOX, GEN, AMP, Complex sulfonamides | Disc diffusion    | $Salmonella enterica$                    | Mostly resistant to fluoroquinolone and cephalosporins                             |
| Adegoke et al., 2015            | Water                              | FLO, TET, GEN, KAN, CHL, NAT, AMC, SMX, SXI, CET, STR | Breakpoint assay  | Pseudomonas sp.                         | Resistant to $> 3$ classes of antimicrobial agent                                   |
| Omuosu et al., 2016             | Vegetables, Cow and Poultry        | TET, FEP, IPM, AMK, CIP, CAR, CAZ | Disc diffusion    | Pseudomonas sp.                         | Mostly resistant to four or more antimicrobial agents                               |
| Ugg et al., 2017                | Water                              | GEN, AMP, OFX, CHL, FOX, TET, NOR, CXM, AMX, LEX, CXC, AMC, COT, ERY, CLI, CIP | Disc diffusion    | $S. aureus Bacillus sp., $E. coli$, $Pseudomonas sp.$ | Resistant to at least three antimicrobial classes |
| Ayandiran and Dalumi, 2017      | Catfish                            | ERY, CIP, TET, OFX, GEN, KAN, CRO, LEX, CXM, CHL, AMP, AMX, AUG, NIT, TET, CLI, COT | Disc diffusion    | Bacillus sp., Clostridium sp., $Alcaligenes faecalis$, $Flavobacterium aquatile$, $Enterobacter dissolvens$, $Corynebacterium striatum$ | Resistant to between four to nine types of antibiotics |
| Lateef and Ojo, 2015             | Dried Injera Fermenting broth, Water for steeping cassava | AUG, GEN, PFX, OFX, SPX, STR, COT, CHL, CIP, AMX, AX, CXM, CRO, CIP, ERY | Disc diffusion    | $S. aureus$, $Salmonella typhimurium$ and $E. coli$, Lactobacillus sp. | Resistant to between two to ten types of antibiotics |
| Adegoke et al., 2019b           | Water                              | GEN, CXM, OFX, CXC, CAZ, CRO, ERY, AUG | Disc diffusion    | $S. aureus$.                            | Resistant to four or more antimicrobial agents                                    |
Table 4. Frequency of isolation of MDR from different food groups in the selected articles.

| Authors                  | Food type    | Type of antibiotics used                                                                 | Method of testing | Mdr bacteria/resistotypes                                                                 | Resistance pattern                                      |
|--------------------------|--------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------|
| Okiki et al., 2018       | None         | AUG, OFX, AMP, CIP, GEN, CAZ, NIT, CXM, STR, LEX, TET, CHL, ERY, PEN                      |                   | *Vibrio parahaemolyticus*, *Proteus mirabilis*, *Campylobacter jejuni*, *Escherichia coli*, *Salmonella enterica* | Resistant to between five to eight antimicrobial drugs   |
| Igbino et al., 2016b     | Milk, cattle | MET, PEN, CLX, AMX, ERY, GEN, KAN, CLN, CHL, SXT, VAX                                   | Disc diffusion    | *Escherichia coli*, *Salmonella enterica*                                               | Resistant to all the antimicrobial agents tested         |
| Titilayo et al., 2015    | Water        | AMK, STR, KAN, NEO, GEN, FEP, CEF, CXM, MEM, IPM, CIP, GAT, NAL, SMT, NIT, CHL, TET, DOX, AMX, AMP | Disc diffusion    | *Salmonella enterica*                                                                  | Resistant to three to ten antimicrobials, but mostly sulfonamides, β-lactams and tetracyclines |
| Chigor et al., 2020      | Vegetables   | AMX, AMP, PEN, CXA, CXM, STR, RIF, MTZ, SMT, TET, VAN, ERY, CLR, CHL, CIP, NOR, TET, IPM | Disc diffusion    | *Salmonella enterica*                                                                  | Resistant to ≥3 class of antimicrobial agent             |
| Adebisi et al., 2019     | Water        | AMK, NEO, STR, TMP, GEN, NET, CEF, CTX, CIP, MEM, IPM, CAZ, SMT, ERY, CHL, TET, SXT, AMX, AMP | Disc diffusion    | *Salmonella enterica*                                                                  | Resistant to four to thirteen antimicrobials             |
| Fakayode et al., 2018    | Water        | AMP, AMG, GEN, KAN, STR, TET, NAL, CIP, SXT, CHL, ERY, VAN, RIF                          | Disc diffusion    | *Salmonella enterica*                                                                  | Resistant to ≥3 class of antimicrobial agent             |
| Adenike et al., 2015     | Cattle, chicken, swine | AMK, AMP, SAM, ATMCPF, FEP, FOX, CPD, CAZ, CRO, CXM, CEF, CIP, ETP, GEN, MEM, TSP, TET, TIM, TOB, SXT, TGC | Broth microdilution with the Sensititre™ system. | *Salmonella enterica*                                                                  | Resistant to three to five antimicrobial agent            |
| Beshir et al., 2017      | Pig          | PIP, PEN, ERY, GEN, KAN, CLI, IPM, MEM, CIP, TET                                        | Disc diffusion    | *Enterococcus faecalis* and *Enterococcus faecium*                                          | Resistant to two to eight antimicrobial agents           |
| Bammigboye et al., 2020  | Water        | LEX, OFX, NAL, PFX, CIP, SXT, STR, GEN, AUG, AX, AMP, CRO, CXM, ERY, AMX                | EUCAST            | *Salmonella enterica*, *Proteus vulgaris*, *E.coli*, *Shigella dysenteriae*, *Pseudomonas aeruginosa*, *Serratia marcescens* and *Staphylococcus aureus* | Resistant to three to ten antimicrobials                  |
| Nwoifor and Ndohukwe 2016 | Vegetables  | ERY, CLX, COT, AUG, TET, GEN, CHL, STR, OFX, NAL, AMX, NIT                             | Disc diffusion    | *Salmonella enterica*                                                                  | Not stated                                              |
| Adesoji et al., 2019c    | Water        | FLO, TET, STR, GEN, KAN, CHL, NAL, AMX, CTF, SMT, AMP, TET, AMP, ERY, RIF, LCM, CIP     | Disc diffusion    | *Salmonella enterica*, *Alcaligenes sp.*, *Proteus mirabilis*, *Morganella sp.*, *Klebsiella pneumoniae*, *Bacillus sp.*, *Proteus vulgaris*, *Morganella morgani* and *Escherichia coli* | Resistant to ≥4 antimicrobial agents                     |

**MET**: Methicillin, **CXC**: Cloxacillin, **PEN**: Penicillin, **AMX**: Amoxicillin, **ERY**: Erythromycin, **GEN**: Gentamicin, **KAN**: Kanamycin, **VAN**: Vancomycin, **CHL**: Chloramphenicol, **SXT**: Sulphamethoxazole/Trimethoprim, **CRO**: Ceftriaxone, **AMP**: Ampicillin, **TET**: Tetracycline, **NAL**: Nalidixic Acid, **CIP**: Ciprofloxacin, **COT**: Cotrimoxazole, **NIT**: Nitrofurantoin, **OFX**: Ofloxacine, **AMI**: Amoxicillin- Clavulanic Acid, **TOO**: Tobramycin, **CAZ**: Ceftazidime, **IPM**: Imipenem, **ETP**: Ertapenem, **FOX**: Cefotaxime, **STF**: Streptomycin, **AUG**: Augmentin, **CMX**: Cefoxime, **CPR**: Cefprozil, **TIC**: Ticarcillin, **CFZ**: Ceftazolin, **LEX**: Cepalexin, **CTX**: Cefotaxime, **MEM**: Meropenem, **SAM**: Ampicillin- Sulbactam, **TSP**: Piperacillin-Tazobactam, **AMK**: Amikacin, **SPT**: Spectinomycin, **ENR**: Enrofloxacine, **LVE**: Levofloxacine, **DOX**: Doxycycline, **SMT**: Sulphamethoxazole, **TMP**: Trimethoprim, **CST**: Colistin, **NEO**: Neomycin, **FLO**: Florfenicol, **CEF**: Cephalexin, **CIP**: Cefepime, **CLI**: Clindamycine, **NOR**: Norfloxacine, **PFX**: Pefloxacine, **SPX**: Sparflonxacin, **AX**: Ampicilin, **CAR**: Carbencillin, **GAT**: Gentamicin, **RIF**: Rifampin, **MTZ**: Metronidazole, **CLR**: Clarithromycin, **NET**: Netilmicin, **ATM**: Aztreonam, **CPD**: Cefpodoxime, **TIM**: Ticarcillin-Clavulanic Acid, **TGC**: Tigecycline, **PIP**: Piperacillin, **CTF**: Ceftiofur, **LCM**: Lincomycin
Augmentin and Ceftriaxone in both smoked fish and suya sampled, including *Staphylococcus* sp., *Escherichia* sp., *Enterobacter* sp., *Shigella* sp., *Bacillus* sp., *Salmonella* sp. and *Proteus* sp. with *Escherichia* sp. having the highest prevalence of 13 out of 35 (37.1%) in smoked fish and 10 out of 46 (21.7%) in suya. Previous research by Odonkor and Addo (2018) reported the prevalence of MDR *Escherichia coli* which were resistant to penicillin (32) representing 32.99%, followed by cefuroxime (28) representing 28%, erythromycin (23) representing 23.71%, tetracycline (21) representing 21.45%, chloramphenicol (18) representing 18.65%, pipemidic acid (13) representing 13.40%, and ampicillin (11) representing 11.32% in drinking water samples to be 48 (positive as MDR) out of a total 97 isolates (49.48%). Although in a lower percentage, Olowe et al. (2018) reported a prevalence of 37 MDR out of 216 (17.1%) of MDR *Escherichia coli* resistant to ticarcillin, tetracycline, trimethoprim, ampicillin, doxycycline, sulfamethoxazole and sulfa-
methoxazole/trimethoprim, levofloxacin, enrofloxacin, ciprofloxacin, ampicillin/sul-
bactam, cefuroxime, cefotaxime, cefazolin, cephalixin, ceftazidime, tobramycin, gent-
tamicin, amoxicillin/clavulanic acid and kanamycin in foods of animal origin. However, in their own reports Ifeanyichikwu et al. (2016); Uzeh et al. (2017); Ahmed et al. (2019); Musa et al. (2020). *Salmonella* sp. was identified as having a prevalence of 31 MDR out of 31 isolates (100) in foods. Meanwhile, Ayandiran and Dahunsi (2017) reported the highest prevalence of MDR in *Bacillus* and *Clostridium* sp. Both were resistant to ofloxacin, cotrimoxazole, ceftriaxone, erythromycin, ciprofloxacin, gentamicin, cephalixin, ampicillin and augmentine. The prevalence of multi-drug resistance among *E. coli* isolates were also supported by Bamigbeyo et al. (2020). They reported iso-
lating an *E. coli* that showed one hundred percent resistance to all the tested antibi-
otics. The reason for the high prevalence of MDR *Escherichia* sp. could be the develop-
ment of biofilms which would offer protec-
tion against antimicrobial agents which may lead to chronic infections and treatment
problems (Olowe et al., 2018). Also, as *E.
coli* is a normal flora of humans, the han-
dling of food during processing may have contributed to its spread (Rasheed et al.,
2014). Considering that most of the sam-
ples were animal-based proteins and vege-
tables, *E. coli* inhabiting the gut of the ani-
mals (Maneilla-Becerra et al., 2019) may have migrated to the meat of the ani-
mals during slaughter and processing. The use of contaminated water in vegetable
farms may also result in the spread of MDR
*E. coli*. Industrial and household effluents dumped directly into rivers, which are pri-
mary sources of water in vegetable farms, may contribute to the MDR patterns (Titilawo et al., 2015). Chigoro et al. (2020) corroborated this when they reported MDR bacteria from wastewater samples. Once accumulated in the environment, bacteria species may begin to transmit antibiotics resistance genes amongst themselves pos-
ing serious public health concerns.

**MDR bacteria related to food groups**

In the food groups, the highest percent-
age of MDR bacteria (666 out of 1326;

| MDR Bacteria       | S/West | S/East | S/South | N/West | N/East | N/Central | Total |
|---------------------|--------|--------|---------|--------|--------|-----------|-------|
| *Escherichia* sp.   | 6      | 1      | 1       | 1      | NIL    | 1         | 10    |
| *Staphylococcus* sp.| 2      | NIL    | 3       | 2      | 1      | 1         | 9     |
| *Salmonella* sp.    | 3      | 1      | NIL     | NIL    | NIL    | 3         | 7     |
| *Pseudomonas* sp.   | 3      | NIL    | 1       | NIL    | NIL    | 4         |       |
| *Bacillus* sp.      | 2      | NIL    | 1       | 1      | NIL    | 1         | 5     |
| *Shigella* sp.      | 2      | NIL    | NIL     | 1      | NIL    | 3         |       |
| *Proteus* sp.       | 1      | NIL    | 1       | 1      | NIL    | 3         |       |
| *Klebsiella* sp.    | 1      | NIL    | NIL     | 1      | NIL    | 2         |       |
| *Enterobacter* sp.  | NIL    | NIL    | 1       | 1      | NIL    | 2         |       |
| *Clostridium* sp.   | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Alcaligenes* sp.   | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Lactobacillus* sp. | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Plesomonas* sp.    | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Serratia* sp.      | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Vibrio* sp.        | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Photobacterium* sp.| 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Campylobacter* sp. | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Neisseria* sp.     | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Moraxella* sp.     | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Propionibacterium* sp. | 1 | NIL | NIL | NIL | NIL | 1 |       |
| *Amycolatopsis* sp. | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Eubacterium* sp.   | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Chromobacterium* sp.| 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Tropheryma* sp.    | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |
| *Enterococcus* sp.  | 1      | NIL    | NIL     | NIL    | NIL    | 1         |       |

NIL: No organism recorded in region.
### Table 6. Percentage Resistance/Susceptibility for each antibiotic used in all included articles.

| Antibiotics | No. Used | No. Resistant | No. Susceptible | % Resistance | % Susceptibility |
|-------------|----------|---------------|-----------------|--------------|-----------------|
| MET         | 2        | 2             | 0               | 100          | 0               |
| CXR         | 2        | 0             | 2               | 0            | 100             |
| PEN         | 6        | 6             | 0               | 100          | 0               |
| AMK         | 13       | 9             | 4               | 69.2         | 30.78           |
| ERY         | 18       | 12            | 6               | 66.7         | 33.3            |
| GEN         | 22       | 12            | 10              | 54.5         | 45.5            |
| KAN         | 9        | 4             | 5               | 44.4         | 55.6            |
| VAN         | 6        | 4             | 2               | 66.7         | 33.3            |
| CHL         | 18       | 8             | 10              | 44.4         | 55.6            |
| SXT         | 12       | 9             | 3               | 75           | 25              |
| CRO         | 8        | 5             | 3               | 62.5         | 37.5            |
| AMP         | 14       | 13            | 1               | 92.9         | 7.1             |
| TET         | 19       | 16            | 3               | 84.2         | 15.8            |
| TIC         | 1        | 1             | 0               | 100          | 0               |
| SPT         | 1        | 0             | 1               | 0            | 100             |
| ERY         | 18       | 12            | 6               | 66.7         | 33.3            |
| RIF         | 3        | 1             | 2               | 33.3         | 66.7            |
| LCM         | 1        | 0             | 1               | 100          | 0               |
| AX          | 2        | 2             | 0               | 100          | 0               |
| DOX         | 2        | 2             | 0               | 100          | 0               |
| ENR         | 14       | 13            | 1               | 92.9         | 7.1             |
| SXT         | 12       | 9             | 3               | 75           | 25              |
| VPS         | 1        | 0             | 1               | 0            | 100             |
| NET         | 1        | 0             | 1               | 0            | 100             |
| AMK         | 10       | 8             | 2               | 80           | 20              |
| OFX         | 10       | 8             | 2               | 80           | 20              |
| AMK         | 7        | 5             | 2               | 71.4         | 28.6            |
| TOB         | 3        | 2             | 1               | 66.7         | 33.3            |
| CQX         | 9        | 5             | 4               | 55.6         | 44.4            |
| ETP         | 7        | 5             | 2               | 28.6         | 71.4            |
| FOXN        | 5        | 2             | 3               | 40           | 60              |
| STR         | 13       | 9             | 4               | 69.2         | 30.8            |
| AUG         | 7        | 7             | 0               | 100          | 0               |
| CXM         | 12       | 7             | 5               | 58.3         | 41.7            |
| CPR         | 1        | 1             | 0               | 100          | 0               |
| TCZ         | 1        | 1             | 0               | 100          | 0               |
| CPZ         | 2        | 2             | 0               | 100          | 0               |
| LEX         | 6        | 3             | 3               | 50           | 50              |
| CTX         | 4        | 1             | 3               | 75           | 25              |
| MEM         | 5        | 4             | 1               | 20           | 80              |
| SAM         | 2        | 2             | 0               | 100          | 0               |
| TIZ         | 3        | 2             | 1               | 66.7         | 33.3            |
| AMK         | 5        | 5             | 0               | 100          | 0               |
| SPT         | 1        | 0             | 1               | 0            | 100             |
| ENR         | 1        | 1             | 0               | 100          | 0               |
| LEX         | 1        | 1             | 0               | 100          | 0               |
| DOX         | 2        | 2             | 0               | 100          | 0               |
| SMT         | 2        | 2             | 0               | 100          | 0               |
| TMP         | 3        | 2             | 1               | 66.7         | 33.3            |
| CST         | 1        | 0             | 1               | 100          | 0               |
| NEO         | 3        | 1             | 2               | 33.3         | 66.7            |
| FLO         | 2        | 2             | 0               | 100          | 0               |
| CEF         | 4        | 4             | 0               | 100          | 0               |
| FEP         | 5        | 4             | 1               | 66.7         | 33.3            |
| CLI         | 4        | 2             | 2               | 50           | 50              |
| NOR         | 3        | 2             | 1               | 66.7         | 33.3            |
| PEN         | 2        | 2             | 0               | 100          | 0               |
| SFX         | 1        | 1             | 0               | 100          | 0               |
| AX          | 2        | 2             | 0               | 100          | 0               |
| CAR         | 1        | 1             | 0               | 100          | 0               |
| GAT         | 1        | 0             | 1               | 100          | 0               |
| RIF         | 3        | 1             | 2               | 33.3         | 66.7            |
| MTZ         | 1        | 1             | 0               | 100          | 0               |
| CLI         | 1        | 1             | 0               | 100          | 0               |
| NET         | 1        | 0             | 1               | 0            | 100             |
| ATM         | 1        | 1             | 0               | 100          | 0               |
| CIPD        | 1        | 0             | 1               | 0            | 100             |
| TIM         | 1        | 1             | 0               | 100          | 0               |
| TGC         | 1        | 1             | 0               | 100          | 0               |
| PIP         | 1        | 0             | 1               | 0            | 100             |
| CTP         | 1        | 1             | 0               | 100          | 0               |
| LCM         | 1        | 0             | 1               | 0            | 100             |

METH: Methicillin, CIX: Cloxacillin, PEN: Penicillin, AMK: Amoxicillin, ERY: Erythromycin, GEN: Gentamicin, KAN: Kanamycin, VAN: Vancomycin, CHL: Chloramphenicol, STM: Sulphamethoxazole/Trimethoprim, CRO: Cefuroxime, AMP: Ampicillin, TET: Tetracycline, NAL: Nalidixic Acid, CIP: Ciprofloxacin, COT: Cotrimoxazole, NFT: Norfloxacin, OFX: Ofloxacin, AMK: Ampicillin; Cefaclor; CRO: Cefuroxime, ATM: Amoxicillin/Clavulanate, AMC: Ampicillin-Sulbactam, IPM: Imipenem, ETP: Ertapenem, FOX: Cefoxitin, STR: Streptomycin, AUG: Augmentin, CFX: Ceftoxitin, CPR: Cefprozil, TIC: Ticarcillin, CFZ: Cefazolin, LEX: Cephalexin, CTX: Cefotaxime, MEM: Meropenem, SAM: Amoxicillin-Sulbactam, TEP: Piperacillin-Tazobactam, AMK: Amikacin, STR: Spectinomycin, ENR: Enrofloxacin, LEX: Levofloxacin, DOX: Doxycycline, SXT: Sulphamethoxazole, TMP: Trimethoprim, GST: Colistin, NEO: Neomycin, FLO: Florfenicol, CEP: Cephalothin, FEP: Cefepime, CLI: Clindamycin, NOR: Norfloxacin, PFX: Pefloxacin, SPX: Sparfloxacin, AX: Ampiclox, CAR: Carbencillin, GAT: Gentamicin, RIF: Rifampin, MTZ: Metronidazole, CIP: Ciprofloxacin, NET: Neomycin, AMK: Amoxicillin, CFP: Cefpodoxime, TIM: Ticarcillin-Clavulanic Acid, TGC: Tegopenil, PIP: Piperacillin, CTP: Cefuroxime, LCM: Lincosycin
(50.23%) was observed in drinks which majorly includes water and nando; a local drink from cow’s milk. Highest resistotype found in drinks was E. coli which accounted for 118 of the 666 (17%) MDR bacteria isolated from drinks. This result excludes Fakayode et al., (2018), where results for gram negative MDR was presented in group as higher 150 of 236 (63.6%) compared gram positive 27 of 94 (28.7%). In the gram-negative group occurrence of E. coli (39) was next only to Actinobacteri (42), hence may have contributed most to the gram-negative bacteria MDR group. This result corroborated previous research which reported that all the organisms isolated from drinking water were multi-drug resistant (Ogu et al., 2017; Adesiyen et al., 2019; Adesoji et al., 2019; Bamigboye at al., 2020). This study also found protein-based foods such as beef, poultry and other animal food products to harbor the second highest percentage of MDR bacteria; 540 out of 1326 (40.72%). Highest resistotype found in protein-based food was Enterococcus; 129 out of 540 (23.9%) MDR bacteria, and Salmonella 128 out of 540 (23.7%) MDR bacteria This is in line with reports by Uzeh et al. (2017); Ahmed et al. (2019); Musa et al. (2020) that reported a high percentage of MDR bacteria in protein-based foods. Prevalence of MDR E. coli isolated from cattle, chicken and swine have also been reported by Adenipekun et al. (2015). The high prevalence of MDR bacteria in protein-based animal foods (predominantly chicken and poultry products) could be due to inappropriate use of antibiotics in treating livestock as resistant organisms present in the animal gut can contaminate the animal products during the slaughtering and processing of the animals for food (CDC, 2016).

Antibiotics related to MDR
In all the reports reviewed, the highest resistances observed in sulphamethoxazole (100%) (Adesiyen et al., 2019), cefuroxime, gentamicin, amoxicillin/clavulanate and ciprofloxacin (66.7%) were observed among E. coli from “suya” (Adesoji et al., 2019), tetracycline, cefoxitin and sulphonamethoxazole (40.9 - 77.3 %) (Adesoji et al., 2015), ampicillin, cefotaxime and cefazidime (100%) (Ahmed et al., 2019), erythromycin, ciprofloxacin, gentamicin, cephalixin, ceftriaxone, and ampicillin (100%) (Ayandiran and Dahunsi, 2017), clindamycin (99%) and (100%) in farms A and B respectively as reported in the article (Beshiru et al., 2017), penicillin, vancomycin and erythromycin (98%) (Chigor et al., 2020), ampicillin (80.9%) (Fakayode and Ogunjobi, 2028), methionine, penicillin, chloramphenicol, sulphamethoxazole/trimethoprim (Igbinosi et al., 2016), cefoxitin (100%) (Kwoji et al., 2019), ampicillin (100%) (Musa et al., 2020), cefuroxime (82%) (Amaeze et al., 2016), ceftazidime (91%) (Odumosa et al., 2015), sulphamethoxazole (100%) (Titilawo et al., 2015), amoxicillin and amoxicillin-clavulanate (100%) (Uzeh et al., 2017). It is not surprising that penicillin showed the highest prevalence in most of the articles included in this study. The high frequency of use of Beta lactams, which are characterized by low toxicity may have contributed to this result (Chigor et al., 2020). Similarly, thirteen articles reported resistance to ampicillin out of the fourteen articles which screened for MDR resistance to ampicillin. Titilawo et al. (2015), found ampicillin-resistant gene to be predominant in the environment, thus transfer of the resistant gene among bacteria isolate is possible. The result for ampicillin is also supported by Adenipekun et al. (2015) and Chigor et al. (2020).

Conclusions
This review has established the prevalence of multi-drug resistant bacteria in foods and drinks in Nigeria. The study has established that more MDR bacteria have been isolated from protein-based foods and from drinks. The study also reports a greater prevalence of Escherichia sp. among the species of MDR bacteria reportedly isolated. The presence of MDR bacteria in foods and drinks can lead to several public health issues, especially in Nigeria and therefore public health personnel need to ensure critical control during the production and handling of foods and drinks, as well as create more awareness as concerning proper hygienic practices to combat the spread of MDR bacteria.

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