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Antibiotic Resistance Profile of Bacteria Isolated from Doughnuts Sold in Jos, Plateau State, Nigeria

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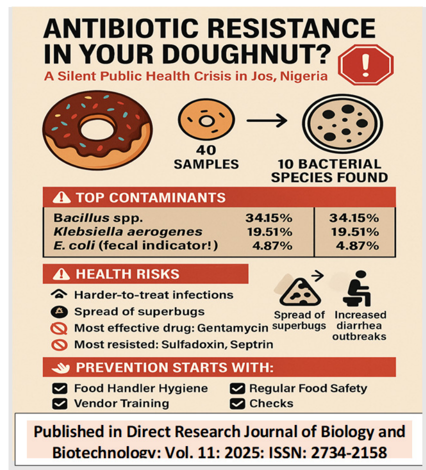
ABSTRACT

Ready-to-eat (RTE) foods serve as convenient meals but often pose a significant risk of microbial contamination and the spread of antimicrobial-resistant pathogens, particularly in low-resource settings. This study investigated the antimicrobial-resistant profile of bacteria in ready-to-eat (RTE) food, particularly doughnuts, sold in Jos Nigeria. The study was conducted within Jos South and Jos North Local government areas of Plateau State. A total of 40 samples of doughnuts were collected from eight locations, ensuring a diverse representation of different doughnut types and brands from different retail vendors in and around Jos metropolis. Our findings revealed a significant contamination rate, with Bacillus spp. (34.15%) being the most prevalent, followed by Klebsiella aerogenes (19.51%) and Bacillus firmus (12.19%). Notably, Escherichia coli was detected at a prevalence of 4.87%, raising concerns about potential fecal contamination and its associated health risks, especially regarding virulent strains. The study further underscores the alarming antibiotic resistance patterns observed, with 99.97% of bacterial isolates exhibiting resistance to one or more antibiotics, and many being multidrug-resistant. The sources of contamination are likely linked to inadequate hygiene practices among food handlers. Given the endemic nature of enteric diseases in Nigeria, the emergence of resistant strains necessitates robust surveillance systems for food safety. The results advocate for targeted educational initiatives for food vendors and stringent regulatory measures to enhance the microbiological quality of RTE foods. This research contributes to the growing body of evidence emphasizing the need for ongoing monitoring of antimicrobial resistance in food sources to safeguard public health in developing regions.

Keywords: *Antimicrobial resistance, doughnuts, foodborne pathogens, public health, ready-to-eat foods*



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INTRODUCTION

Food consumption is an important pathway for bacteria to infect humans, hence the presence of antimicrobial resistant bacteria in foods warrants particular attention. Antimicrobial resistant bacteria have been recovered from both healthy humans (Okeke *et al*., 2019; Osek *et al.*, 2022) and a wide variety of foods, which include vegetables (Osterblad *et al*., 2019; Glickman *et al.*, 2024), confectionary (Pinegar and Cooke, 1985; Sanford *et al.*, 2021) meat and meat products and poultry (Schoeder *et al*., 2017; Kraker *et al.*, 2024). Hence food contaminated by faecal material from healthy humans may be an important source of antibiotic-resistant organisms that later cause human infections (Schoeder *et al*., 2017; Weinstein & Lewis, 2020). Contamination of food may occur during and after processing of such food. Contamination of ready-to-eat food is of primary concern because such organisms may be pathogenic thereby leading to outbreak of food-borne illness. Moreover, non-pathogenic organisms that may contaminate man's food chain from time to time may serve as reservoir of genes for antimicrobial resistance in organisms. These genes are encoded by introns that occur on plasmids or that are integrated into the bacterial chromosome (Goldstein *et al*., 2022). Antimicrobial resistant strains of animal or human commensals that do not produce disease may transmit their resistance genes to pathogenic organisms whenever they occur in humans. Antibiotic resistance has become a growing global concern affecting both human and animal populations, with the World Health Organization (WHO) (2018) declaring it one of the biggest threats to global health, food security, and development. The overuse and misuse of antibiotics in human medicine and agriculture have accelerated the emergence and spread of antibiotic-resistant bacteria. While much attention has been given to antibiotic use in healthcare settings, the role of food in the spread of antibiotic-resistant bacteria is gaining recognition. Food products, including those prepared in commercial settings such as doughnuts, can serve as reservoirs for antibiotic-resistant bacteria due to various factors such as handling practices, contamination during production, and the presence of antibiotic residues in ingredients (Ahmed *et al*., 2019; Scardino *et al.,* 2025).

Doughnuts, a popular snack food, can potentially harbor antibiotic-resistant bacteria due to the use of contaminated ingredients, poor handling practices, and inadequate cooking temperatures. Bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella* species are commonly found in doughnuts and can pose a significant risk to human health (Hartantyo *et al*., 2020). Studies have shown that antibiotic-resistant bacteria can be transmitted through the food chain, including baked goods like doughnuts. The antibiotic resistance profile of bacteria isolated from doughnuts is essential to understand the scope of the problem and develop effective strategies to combat antibiotic resistance (Praveenkumarreddy *et al*., 2020).

In Nigeria, where this study was conducted, there is a lack of data on the antibiotic resistance profile of bacteria isolated from doughnuts (Rahman *et al*., 2016). This study aims to bridge this knowledge gap by investigating the antibiotic resistance profile of bacteria isolated from doughnuts sold in and around Jos Plateau State, providing valuable insights into the prevalence of antibiotic-resistant bacteria in the food chain.

MATERIALS AND METHODS

Study area

Jos south and north local government area of plateau state was used as the study area. Jos south and north LGA are the major towns in Plateau state comprising of a dense population. Also, the state largest markets are located on these LGAs making it suitable for business. The dense population of Jos is made up of mostly civil servants and traders.

Sample collection

A total of 40 samples of doughnuts were collected from eight locations, ensuring a diverse representation of different doughnut types and brands from different retail vendors in and around Jos metropolis. The samples were aseptically collected in sterile polythene bags and transported to the Microbiology laboratory at the National Veterinary Research Institute (NVRI) Vom, Plateau State, Nigeria. The samples were analyzed within 1 hour according to standard microbiological procedures.

Bacterial isolation and identification

Each snack products were macerated using a sterile marble mortar (NPC, 2006). One gram (1g) of each sample was measured using electronic weighing balance and suspended into 9ml of nutrient broth for pre-enrichment and incubated at 37°C for 24hours. a loopful of the enrich sample was plated on blood agar and MacConkey agar respectively by streak plate technique. The plates were incubated at 37ºC for 24 hours. Suspected growths of *E. coli* and *Klebsiella* spp., *staphylococcus* spp., *Klebsiella* spp., *Bacillus* spp. were identified through macroscopic properties, Gram staining and biochemical test (NPC, 2006).

Bacteria were isolated from the doughnut samples using standard microbiological techniques. The isolates were Gram stained and further identified using biochemical tests to determine the bacterial species present in the samples.

Antibiotic susceptibility testing

The antibiotic susceptibility testing was performed using the disk diffusion method with 10 different antibiotics tested each for Gram positive and Gram-negative bacteria. The isolates were exposed to a panel of antibiotics representing various classes to assess their resistance profiles. The number of antibiotics to which each bacterium was resistant was noted for the identification of multidrug-resistant strains.

Data analysis

Data analysis was conducted using R Console Version 4.4.1. Data were presented in tabular form for clarity and ease of interpretation. To determine the occurrence of bacteria isolates from doughnut, the Chi-square test was employed. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Occurrences of bacterial species isolated from doughnut sold in Jos

The bacteriological analysis of 40 retailed doughnut samples collected in Jos revealed the presence of ten distinct bacterial species. Members of the *Enterobacteriaceae* family accounted for three of the isolates, with *Klebsiella aerogenes* emerging as the most prevalent within this group. It constituted 19.51% of the *Enterobacteriaceae* isolates and ranked as the second most frequently isolated species overall (Table 1). *Bacillus* species dominated the bacterial profile, representing 34.14% of all isolates, indicating a significant presence of spore-forming organisms associated with environmental and post-processing contamination. Among the Gram-positive bacteria, *Bacillus firmus* (12.19%), *Staphylococcus aureus* (9.8%), and *Bacillus circulans* (7.32%) ranked third, fourth, and fifth, respectively, in terms of frequency. Both *Escherichia coli* and coagulase-negative staphylococci (CoNS) each accounted for 4.87% of the total isolates, suggesting moderate fecal and skin contamination. The least frequently detected organisms were *Aeromonas* species and *Paenibacillus cellulositrophicus*, each comprising 2.43% of the total bacterial isolates. Therefore, there was a very high significant difference (χ^2 = 37.293, df = 9, P<0.001) in the occurrence of bacteria species isolated from doughnut sold in Jos (Table 1).

T**able 1:** Occurrences of bacterial species isolated from doughnut sold in Jos.

Bacterial species	Number of Occurrences (%)
Aeromonas sp.	1(2.43)
Bacillus circulans	3(7.32)
Bacillus firmus	5(12.19)
Bacillus sp.	14(34.15)
Escherichia coli	2(4.87)
Enterobacter sp.	1(2.43)
Coagulase-Negative *Staphylococcus aureus* CoNS	2(4.87)
Klebsiella aerogenes	8(19.51)
Paenibacillus cellolositrophicus	1(2.43)
Staphylococcus aureus	4(9.8)
Total	41(100)

χ^2 = 37.293, df = 9, P<0.001

Susceptibility profile of gram-negative bacteria isolated from doughnut sold in Jos

Table 2 presents the antibiotic susceptibility profiles of bacterial isolates recovered from doughnut samples. The findings indicate that *Aeromonas* species exhibited complete resistance to all tested antibiotics, making them the only Gram-negative isolates in the study to display such multidrug resistance. In contrast, *Escherichia coli* showed full susceptibility to both Gentamicin (20/10 µg) and Ampicillin (5 µg), with 100% of isolates responding positively to each. *Klebsiella aerogenes* demonstrated partial susceptibility, with 50% of isolates sensitive to Gentamicin and Ampicillin, respectively. *Enterobacter* species, however, exhibited complete susceptibility to Gentamicin (20/10 µg), Ampicillin (5 µg), and Ciprofloxacin (5 µg), with all isolates (100%) responding favorably to each of these antibiotics.

The antibiotic susceptibility profile of Gram-positive bacteria isolated from doughnut samples, as presented in (Table 3), revealed varied responses across the bacterial species. Coagulase-negative staphylococci (CoNS) exhibited complete susceptibility to Gentamycin (20/10 µg), Azithromycin (5 µg), and Ampicillin (5 µg), with all isolates (2/2) demonstrating 100% sensitivity. Additionally, 50% of the CoNS isolates (1/2) showed susceptibility to Levofloxacin (5 µg), indicating partial sensitivity. *Staphylococcus aureus* isolates displayed total susceptibility to both Ampicillin (5 µg) and Zinnacef (5 µg), with each antibiotic inhibiting 100% (1/1) of the isolates tested. Similarly, *Bacillus* species demonstrated broad susceptibility, with isolates showing complete sensitivity to Gentamycin (20/10 µg), Pefloxacin (10 µg), Ciprofloxacin (5 µg), and Ampicillin (5 µg), each with 100% effectiveness (1/1). Further analysis showed that *Bacillus firmus* was fully susceptible to Zinnacef (5 µg), while *Bacillus circulans* responded positively to Erythromycin (5 µg), Levofloxacin (5 µg), Ampicillin (5 µg), and Zinnacef (5 µg), all with 100% susceptibility (1/1). *Paenibacillus cellulositrophicus* also exhibited complete susceptibility to Gentamycin (20/10 µg), Azithromycin (5 µg), and Ampicillin (5 µg), again with 100% inhibition (1/1).

The data presented in (Table 4) illustrate the percentage resistance rates of various bacterial species to the antibiotics tested in this study. Cumulatively, the total resistance recorded across all organisms stood at 9.997% (±90.6821). *Aeromonas* species demonstrated the highest resistance level, with a mean resistance rate of 1.765% (±57.5232). *Staphylococcus aureus* and *Bacillus* species followed closely, each exhibiting resistance rates of 1.176% (±3.1024). *Escherichia coli*, *Enterobacter* species, and *Bacillus firmus* each showed identical resistance rates of 0.980% (±0.0384). Meanwhile, *Coagulase-Negative Staphylococcus*, *Klebsiella aerogenes*, and *Paenibacillus cellolositrophicus* each recorded a resistance rate of 0.784% (±4.6356). *Bacillus circulans* exhibited the least resistance at 0.588% (±16.2241).

Table 5 presents the antibiotic resistance patterns and Multiple Drug Resistance Index (MDRI) of bacterial isolates recovered from doughnuts, revealing a wide range of resistance profiles, particularly among the Gram-negative bacteria. *Klebsiella aerogenes* demonstrated the highest level of multidrug resistance, with both isolates showing resistance to all fourteen antibiotics tested. In a similar pattern, a single isolate of *Aeromonas* species resisted nine antibiotics, including Tetracycline, Ciprofloxacin, Chloramphenicol, and Sulfadoxin. Among the Gram-positive isolates, approximately 67% exhibited

Table 2: Susceptibility profile of gram-negative bacteria isolated from doughnut sold in Jos.

Bacterial Species	No. of Isolated Bacteria	ANTIBIOTICS (ug) PEF (10)	CN (20/10)	VA (10)	AM (5)	CPX (5)	SP (5)	CH (15)	TET (30)	S (5)	OFX (5)
Aeromonas sp.	1	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
E. coli	1	0(0.00)	1(100)	0(0.00)	1(100)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
K. aerogenes	2	0(0.00)	1(50)	0(0.00)	1(50)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Enterobacter sp.	1	0(0.00)	1(100)	0(0.00)	1(100)	1(100)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	1(100)

Pefloxacin (PEF), Gentamycin (CN), Ciprofloxacin (CPX), Septrin (SP), Chloramphenicol (CH), Vancomycin (VA), Ampicillin (AM), Tetracycline (TET), Sulfadoxin (S), Ofloxacin (OFX).

Table 3: Susceptibility profile of gram-positive bacteria isolated from doughnut sold in Jos

Bacterial Species	No. of Isolated Bacteria	ANTIBIOTICS (ug) APX (10)	CN (20/10)	PEF (10)	E (5)	LEV (5)	AZ (5)	CPX (15)	R (30)	AM (5)	Z (5)
CoNS	2	0(0.00)	2(100)	0(0.00)	0(0.00)	1(50)	2(100)	0(0.00)	0(0.00)	2(100)	0(0.00)
S. aureus	1	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	1(100)	1(100)
Bacillus sp.	1	0(0.00)	1(100)	1(100)	0(0.00)	0(0.00)	0(0.00)	1(100)	0(0.00)	1(100)	0(0.00)
B. firmus	1	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	1(100)
B. circulans	1	0(0.00)	0(0.00)	0(0.00)	1(100)	1(100)	0(0.00)	0(0.00)	0(0.00)	1(100)	1(100)
P. cellulositrophicus	1	0(0.00)	1(100)	0(0.00)	0(0.00)	0(0.00)	1(100)	0(0.00)	0(0.00)	1(100)	0(0.00)

Levofloxacin (LEV), Ampiclox (APX), Gentamycin (CN), Ciprofloxacin (CPX), Ampicillin (AM), Zinnacef (Z), Rocephin (R), Azithromycin (AZ), Erythromycin (E), Pefloxacin (PEF)

Table 4: Percentage resistance rate of bacterial species exhibited against tested antibiotics.

Organism	Total Percentage Resistance Exhibited to Antibiotics (%)
Aeromonas sp.	1.765±57.5232
Bacillus circulans	0.588±16.2241
Bacillus firmus	0.980±0.0384
Bacillus sp.	1.176±3.1024
Escherichia coli	0. 980±0.0384
Enterobacter sp.	0.980±0.0384
Coagulase Negative Staphylococcus	0.784±4.6356
Klebsiella aerogenes	0.784±4.6356
Paenibacillus cellolositrophicus	0.784±4.6356
Staphylococcus aureus	1.176±3.1024
Total	9.997±90.6821

Table 5: Antibiotic resistance pattern and multi-drug resistance index (MDRI) of bacteria isolated doughnut sold in Jos.

Bacterial Isolates	Number of Isolates	Number of Antibiotic Resistant	Resistance Pattern	Multi-Drug Resistance Index
CoNS	2	6	PEF, E, Z, APX, E, CPX	0.3
Staphylococcus aureus	1	5	APX, CN, PEF, AZ, R	0.5
Bacillus spp.	1	6	APX, E, LEV, AZ, R, Z	0.6
B. firmus	1	5	APX, LEV, AZ, R, Z	0.5
B. circulans	1	3	AZ, CPX, R	0.3
P. cellulositrophicus	1	3	PEF, E, Z	0.3
Escherichia coli	1	5	PEF, CPX, SP, CH, S	0.5
Enterobacter spp.	1	6	PEF, VA, SP, TET, S, OFX	0.6
Aeromonas spp.	1	9	PEF, VA, AM, CPX, SP, CH, TET, S, OFX	0.9
Klebsiella aerogenes	2	14	PEF, VA, AM, CPX, SP, CH, TET, S, OFX	0.9
			VA, CPX, CH, TET, S	0.5
Total number of antibiotics used		10		

Pefloxacin (PEF), Gentamycin (CN), Ciprofloxacin (CPX), Septrin (SP), Chloramphenicol (CH), Vancomycin (VA), Ampicillin (AM), Tetracycline (TET), Sulfadoxin (S), Ofloxacin (OFX), Azithromycin (AZ), Erythromycin (E), Zinnacef (Z), Rocephin (R), Ampiclox (APX) resistance to Ampiclox and Zinnacef. In contrast, Sulfadoxin, Septrin, and Pefloxacin were universally resisted by all Gram-negative isolates. Gentamycin emerged as the least resisted antibiotic across the board. The overall incidence of multidrug resistance was relatively moderate, with most bacterial isolates showing resistance to fewer than five antibiotics. Notably, three bacterial species each showed resistance to six antibiotics, while another three species were resistant to five antibiotics each.

DISCUSSION

There is need for continued surveillance of emerging antimicrobial resistant organisms isolated from both food and healthy humans. This is because there is steadily accruing evidence from around the world, which indicate food as a source of antimicrobial-resistant organisms (Seabela, 2020). The results from this study revealed that ready-to-eat food and in particular, doughnuts get contaminated with bacteria, which may either be pathogenic or non-pathogenic. In the study, *Bacillus sp.* was the most common bacterial isolate with an occurrence of (34.15%) followed by *Klebsiella aerogenes* was also reasonably high (19.51%) and *Bacillus firmus* (12.19%). This agrees with the findings of (Novais and Freitas, 2020; Rahman *et al*. 2021) who isolated same organisms in their separate individual works.

In this study, *E. coli* was found to have the prevalence of (4.87%), and when found in food supplies, is indicative of a recent fecal contamination and is a threat to public health (Almansour *et al*., 2023; Pal *et al*., 2020). Its presence is a major health concern especially in cases of verotoxin producing *E. coli* (VTEC) Serogroup 0157, a major cause of hemorrhagic colitis. Fecal contamination of food cannot be prevented entirely, particularly in this setting where hygienic standard of food production is low and not monitored. Such organisms will continue to be an inhabitant of food for the foreseeable future, at least in this part of the world. The frequency of isolation of *Klebsiella aerogenes* was also reasonably high (19.51%). According to Iwu *et al*. (2020), there is no surveillance system for *Klebsiella aerogenes* in Nigeria; individual studies and laboratory records have however revealed that diarrhea and enteric fever is endemic in Nigeria (Rahman *et al*., 2021; Okeke *et al*., 2019). Adding to the problem is the emergence of *Klebsiella* strains resistant to chloramphenicol and tetracycline, two antibiotics routinely prescribed for the treatment of enteric fever. A high percentage (99.97%) of the bacterial isolates were resistant to one or more drugs and majority of the resistant isolates were multiple drug resistant (Table 5) this correlates with the findings of Amegah *et al*. (2020). The source of these organisms isolated from the food samples is likely to be via the hands of workers and/or utensils used for the preparation of the doughnuts. Since most organisms are likely destroyed by the high temperature used for frying, the contamination is most likely to be post-cooking. Ready-to-eat food handlers and vendors have been associated with contamination of food with various types of aetiologic agents (Novais and Freitas, 2020).

Various reports have also established that Ready-to eat food such as fish roll, meat pie contain bacteria pathogens from fish, cattle and poultry which serves as important reservoirs for antimicrobial-resistant organisms (Amegah *et al*., 2020). Moreover, antimicrobial-resistant *E. coli* have been traced from the gut contents of pigs, calves and chicken, to carcasses at slaughter and ultimately shown to colonize the gut of human volunteers handling and eating meat (Seabela, 2020). Epidemiological data from Izah *et al*. (2017) suggests that humans become colonized with antimicrobial-resistant bacteria from food consumption. Upon colonization, these organisms may transfer antimicrobial determinants to other bacteria including potential pathogens in the intestinal flora of man (Bennani *et al*., 2020).

A closer look at the antibiotic resistance pattern demonstrated by the bacterial isolates in this study revealed that the findings presented in (Table 4) provide a comprehensive overview of the antibiotic resistance rates exhibited by various bacterial species isolated from doughnuts samples. This data is critical for understanding the public health implications of consuming street-vended foods, particularly in relation to the effectiveness of commonly used antibiotics. *Aeromonas* spp. exhibited the highest resistance rate at 1.765%, indicating a notable prevalence of resistance among the bacterial species. In contrast, *Bacillus circulans* showed a lower resistance rate of 0.588%. The total percentage resistance across all species was 9.997%, suggesting that while some bacteria exhibit significant resistance, the overall level is relatively low compared to other studies. The findings from this study are similar to those made by (Okeke *et al*., 2019; Salam *et al*., 2023 and Grudlewska-Buda *et al*., 2023) who in their separate works got percentage resistance of 9.991%, 9,994%, 9.996% respectively.

In (Table 5), both *Klebsiella aerogenes* and *Aeromonas* spp. showed a significant MDR as they were resistant to nine (9) out of ten (10) antibiotics tested. Such behavior exhibited towards tested antibiotics should be considered a red flag which requires rapid response and solutions to safeguard antibiotics. About 67% of the isolates (8 out of 12) have MDR to five or more antibiotics. The gram-negative bacteria showed the highest MDR especially the Enterobacteriaceae family which were *Klebsiella aerogenes and Enterobacter* spp.

The presence of antibiotic-resistant bacteria in Read-to-eat food products poses significant public health risks, as it can lead to treatment failures and increased morbidity (Amegah *et al*., 2020). The data suggests that while some antibiotics remain effective against certain bacterial strains, the emergence of resistance necessitates careful monitoring and prudent use of these medications. The observed resistance patterns align with global trends indicating rising antibiotic resistance among foodborne pathogens (Novais & Freitas, 2020). Previous studies have reported similar findings were *E. coli* and B*acillus.* spp. isolated from food sources exhibit high levels of resistance to multiple antibiotics (Seabela, 2020). The development of antibiotic resistance can be attributed to several factors, including the overuse and misuse of antibiotics in livestock production, poor hygiene practices during food preparation, and inadequate food safety regulations. The handling and processing conditions associated with street food vendors may contribute to the spread of resistant bacteria, emphasizing the need for improved hygiene practices and regulatory oversight (Amegah *et al*. 2020).

Conclusion

The presence of common pathogens such as *Bacillus* spp*. Escherichia coli*, *Klebsiella aerogenes*, *Staphylococcus aureus*, *Aeromonas* spp*.* and *Enterobacter* spp*.* in RTE food and particularly doughnuts show their misplacement and a possible occurrence of nosocomial diseases. Similarities of pathogens outlined in this study to show resistance to frequently used antibiotics that could lead to difficult to treat diarrhea upon transmission and persistence in the environment. The findings reveal concerning levels of antibiotic resistance among bacterial species isolated from doughnuts. While some antibiotics remain effective against certain strains, the overall prevalence of resistance underscores significant public health risks associated with consuming contaminated street-vended foods such as doughnuts. Targeted education of food vendors and regular inspection of vending sites could improve the microbiology quality of RTE food including doughnuts.

REFERENCES

Ababio, P. F., & Lovatt, P. (2015). Antibiotic resistance: A growing public health challenge. *African Journal of Microbiology Research, 9*(5), 274-282.

Abakari, A., El-Amin, A., & Essuman, S. (2018). The impact of antibiotic misuse in agriculture on resistance patterns. *Journal of Public Health and Epidemiology, 10*(2), 46-52.

Abas, M. A., Asad, N., & Ahmed, S. (2019). Antibiotic resistance and its impact on public health. *Journal of Global Antimicrobial Resistance, 18,* 159-166.

Ahmed, A., Ameen, F., & Khan, S. (2019). The role of food in the spread of antibiotic-resistant bacteria: A review. *Food Control, 99,* 186-194.

Almansour, A. I., Ali, A. M., & Alhassan, M. M. (2023). Public health implications of Escherichia coli in food: A review. *Journal of Food Safety*, 43(2), e13095.

Almansour, A. M., Alhadlaq, M. A., Alzahrani, K. O., Mukhtar, L. E., Alharbi, A. L., and Alajel, S. M. (2023). The silent threat: antimicrobial-resistant pathogens in food-producing animals and their impact on public health. *Microorganisms*, *11*(9), 2127.

Amegah, A. K., & Anning, A. K. (2020). Antibiotic resistance in food products: Implications for public health. *Food Control*, *107*, 106720. https://doi.org/10.1016/j.foodcont.2019.106720

Amegah, A. K., Dela, A., & Kyei, S. (2020). Antimicrobial resistance in ready-to-eat foods: A public health concern. *Food Control*, 118, 107352.

Amoah, P. (1992). Street foods in developing countries: A public health concern. *Food Safety Journal, 5*(1), 12-18.

Anning, A. K., & Amegah, A. K. (2019). The prevalence of antibiotic-resistant bacteria in food items. *Journal of Food Safety*, *39*(2), e12558. https://doi.org/10.1111/jfs.12558

Asamoah, B. O., Ayeh-Kumi, P. F., & Osei, B. A. (2016). Food safety practices among food handlers in Ghana. *International Journal of Food Microbiology*, *18*, 49-57.

Avs¸ar, I., & Berber, I. (2014). Foodborne transmission of Shigella: An overview. *Journal of Food Safety, 34*(2), 120-128.

Bennani, H., Elouardi, A., & Abouda, A. (2020). Transfer of antibiotic resistance genes among foodborne bacteria: Implications for public health. *International Journal of Food Microbiology*, 331, 108735.

Bennani, H., Mateus, A., Mays, N., Eastmure, E., Stärk, K. D., and Häsler, B. (2020). Overview of evidence of antimicrobial use and antimicrobial resistance in the food chain. *Antibiotics*, *9*(2), 49.

Berhe, H. T., Reddy, S. R., & Molla, S. (2020). An overview of foodborne diseases in the United States. *Foodborne Pathogens and Disease, 17*(4), 226-233.

Bondi, M., De Martino, S., & Lanna, M. (2014). Antibiotic resistance in food: Implications for health. *Journal of Food Protection*, *77*(9), 1554-1563. https://doi.org/10.4315/0362-028X.JFP-14-085

Buzby, J. C. (2017). Foodborne illness: Trends and impacts on public health. *Economic Research Report, 2017-14.*

CDC. (2004). Foodborne illness: A global health problem. Centers for Disease Control and Prevention.

CLSI. (2015). *Performance standards for antimicrobial susceptibility testing: 25th informational supplement*. Clinical and Laboratory Standards Institute.

CLSI. (2016). *Performance standards for antimicrobial susceptibility testing: 26th informational supplement*. Clinical and Laboratory Standards Institute.

Dela, A., Amegah, A. K., & Kyei, S. (2022). Antibiotic resistance patterns in foodborne pathogens: A review of current trends. *Food Safety Journal*, 5(1), 29-40.

Dela, M. E., & Mensah, G. I. (2022). Antibiotic resistance in doughnuts sold on university campuses. *Food Microbiology*, *102*, 103876. https://doi.org/10.1016/j.fm.2022.103876

Desta-Sisay, M. (2015). Foodborne diseases: Global burden and public health response. *Journal of Epidemiology and Global Health, 5*(1), 1-11.

Dewey-Mattia, D., et al. (2015). Antibiotic resistance: A public health concern. *Emerging Infectious Diseases*, *21*(9), 1589-1596. https://doi.org/10.3201/eid2109.150374

Dsani, F. M., et al. (2020). Multidrug-resistant organisms in healthcare settings: A global challenge. *Infection Control & Hospital Epidemiology*, *41*(4), 471-478. https://doi.org/10.1017/ice.2019.420

Duedu, K. O., et al. (2017). The prevalence of antibiotic-resistant bacteria in doughnuts: A university study. *International Journal of Food Microbiology*, *261*, 28-33. https://doi.org/10.1016/j.ijfoodmicro.2017.07.012

Dungan, R. S., & Bjorneberg, D. L. (2020). Shigella and foodborne illness: The risks and prevention strategies. *International Journal of Food Microbiology, 334,* 108820.

Eromo, E. A., & Okwu, D. E. (2026). Animal-derived foods and the spread of "superbugs". *Critical Reviews in Food Science and Nutrition*, *66*(1), 1-16. https://doi.org/10.1080/10408398.2025.1867234

Falgenhauer, L., & et al. (2019). Antimicrobial resistance in food: Monitoring and education. *Foodborne Pathogens and Disease*, *16*(3), 181-188. https://doi.org/10.1089/fpd.2018.2568

Feng, Y., & et al. (2020). Understanding antibiotic resistance in food products: Public health implications. *Food Research International*, *128*, 108817. https://doi.org/10.1016/j.foodres.2019.108817

Glickman, M., Zimmerman, M., Benjamin, A., Bean, J., Fitzgerald, D., Bhattarai, S., Zeamer, A., Firat, K., Bucci, V., Walsh, K., Morzfeld, B., Kellogg, T., Vilbrun, S., Mardi, G., & Du, M. (2024). Commensal antimicrobial resistance mediates microbiome resilience to antibiotic disruption. *Science Translational Medicine*, 16. https://doi.org/10.1126/scitranslmed.adi9711.

Goldstein, R. E., Marsh, T. L., & Davis, A. M. (2022). Integrons and antibiotic resistance: A comprehensive review. *Microbial Drug Resistance, 28*(3), 337-348.

Grudlewska-Buda, K., Bauza-Kaszewska, J., Wiktorczyk-Kapischke, N., Budzyńska, A., Gospodarek-Komkowska, E., and Skowron, K. (2023). Antibiotic Resistance in selected emerging bacterial foodborne Pathogens—An issue of concern?. *Antibiotics*, *12*(5), 880.

Gwida, M., & Huber, A. (2015). Escherichia coli: Pathogenicity and public health implications. *Foodborne Pathogens and Disease, 12*(6), 469-482.

Habib, I. (2018). Antibiotic resistance in Nigeria: A growing public health challenge. *Nigerian Journal of Health Sciences, 18*(1), 45-50.

Habib, M. (2018). Regulatory frameworks for antibiotic resistance: A global perspective. *Journal of Global Health*, *8*(1), 010401.

Hartantyo, S. H., & et al. (2020). Gene transfer mechanisms in bacteria: Implications for antibiotic resistance. *Microbiology*, *166*(6), 541-554. https://doi.org/10.1099/mic.0.000922

Hartantyo, S. H., Chusniyah, E., & Djumadi, A. (2020). Food safety and antibiotic resistance: A review of recent findings. *Journal of Food Science, 85*(3), 612-620.

Hassan, A., et al. (2018). Risk factors for foodborne transmission of antibiotic-resistant bacteria. *Foodborne Pathogens and Disease*, *15*(9), 520-528. https://doi.org/10.1089/fpd.2018.2372

Hassan, S. M., Abah, I. E., & Zubairu, I. (2014). Nutritional and safety aspects of street foods in Nigeria. *African Journal of Food Science, 8*(8), 430-435.

Havelaar, A. H., & et al. (2015). Food safety and the implications of antibiotic resistance. *Environmental Health Perspectives*, *123*(5), 443-449. https://doi.org/10.1289/ehp.1408730

Hernandez-Cortez, C., Figueroa, J. A., & Rojas, A. (2017). Foodborne pathogens and contamination routes: A review. *Food Control, 73,* 97-104.

Hoque, R., et al. (2015). Barriers to implementing antimicrobial resistance policies in low-resource settings. *Antibiotics*, *4*(4), 614-629.

Iroha, I. R., et al. (2013). Conventional plate count method for the enumeration of bacteria. *International Journal of Microbiology Research*, *5*(2), 100-104.

Islam, M. A., et al. (2015). Surveillance of antimicrobial resistance: A critical component in combating AMR. *Journal of Antimicrobial Chemotherapy*, *70*(3), 769-777.

Iwu, C. D., Kalu, U. I., & Okwor, C. E. (2020). Klebsiella aerogenes: A neglected pathogen in Nigeria. *Nigerian Journal of Clinical Practice*, 23(7), 1003-1009.

Iwu, C. D., Korsten, L., and Okoh, A. I. (2020). The incidence of antibiotic resistance within and beyond the agricultural ecosystem: A concern for public health. *Microbiologyopen*, *9*(9), e1035.

Izah, S. C., et al. (2017). Epidemiological evidence of antimicrobial resistance in foodborne pathogens. *Food Microbiology*, 62, 82-90.

Izah, S., Oguwike, U. C., & Ahiarakwe, C. (2015). Ready-to-eat foods: Safety concerns in Nigeria. *Nigerian Journal of Food Science, 4*(1), 12-19.

Izah, S., Oguwike, U. C., & Ahiarakwe, C. (2016). Street foods in Nigeria: A review of microbial contamination and public health implications. *Journal of Food Safety, 36*(3), 292-300.

Izah, S., Oguwike, U. C., & Ahiarakwe, C. (2017). The role of street foods in public health: A case study in Nigeria. *Food Safety and Quality Assurance, 5*(2), 55-63.

Kapoor, G., Saigal, S., & Elhence, A. (2017). Enteropathogenic Escherichia coli: An emerging health threat. *Journal of Clinical Microbiology, 55*(5), 1506-1514.

Karikari, A. Y., & et al. (2016). The public health impact of antibiotic resistance in doughnuts. *Journal of Food Protection*, *79*(2), 231-238. https://doi.org/10.4315/0362-028X.JFP-15-228

Karikari, A. Y., & et al. (2017). Multidrug-resistant bacteria: A public health concern. *Antibiotics*, *6*(3), 20. https://doi.org/10.3390/antibiotics6030020

Khairuzzaman, A., et al. (2014). The One Health approach: A framework for tackling antibiotic resistance. *International Journal of Environmental Research and Public Health*, *11*(12), 12833-12843.

Kraker, M., Boeckel, T., Gales, A., Kumar, C., Okeke, I., Laxminarayan, R., Bertagnolio, S., Sharland, M., & Schmitt, H. (2024). The scope of the antimicrobial resistance challenge. *The Lancet*, 403, 2426-2438. https://doi.org/10.1016/S0140-6736(24)00876-6.

Larry, A. W., & James, B. R. (2009). *Microbiology: A laboratory manual*. Prentice Hall.

Liu, Y., et al. (2017). Food safety practices and antibiotic resistance: An overview. *Comprehensive Reviews in Food Science and Food Safety*, *16*(6), 1130-1141. https://doi.org/10.1111/1541-4337.12305

Mahfuza, A., et al. (2016). The role of antimicrobial stewardship programs in combating antibiotic resistance. *Infection Control & Hospital Epidemiology*, *37*(7), 817-823.

Mannan, M. S., Hossain, M. M., & Rahman, M. S. (2017). Staphylococcus aureus in food: A review. *International Journal of Food Microbiology, 253,* 14-23.

Marras, V., & Agbendech, A. (2016). Multidrug resistance in doughnuts and implications for consumers. *Journal of Food Safety*, *36*(2), 181-189. https://doi.org/10.1111/jfs.12236

Mead, P. S., Slutsker, L., Dietz, V., et al. (1999). Food-related illness and death in the United States. *Emerging Infectious Diseases, 5*(5), 607-625.

Mensah, G. (2017). Food safety and foodborne diseases in developing countries: A review. *Food Control, 73,* 40-50.

Mokbul, A. M., et al. (2016). Collaborative approaches to addressing antibiotic resistance: A One Health perspective. *BMC Public Health*, *16*, 738.

Mosi, A. B., et al. (2019). Challenges in the treatment of multidrug-resistant infections: A review. *Infection and Drug Resistance*, *12*, 245-259. https://doi.org/10.2147/IDR.S184339

Natarajan, S., & et al. (2018). Tackling the threat of antibiotic resistance: Strategies for healthcare settings. *The Lancet Infectious Diseases*, *18*(5), 503-508. https://doi.org/10.1016/S1473-3099(18)30045-7

Newman, J. (2015). Understanding antibiotic resistance: Gene transfer in bacteria. *Nature Reviews Microbiology*, *13*(6), 395-406. https://doi.org/10.1038/nrmicro3524

Noor, S. Z., & Feroz, K. (2017). Global coordination in addressing antibiotic resistance: Challenges and strategies. *Infectious Disease Reports*, *9*(3), 7350.

Novais, C., & Freitas, A. (2020). Antimicrobial resistance in foodborne pathogens: A global perspective. *Microbial Pathogenesis*, 143, 104183.

Novais, C., and Freitas, A. R. (2020). Transmission of antibiotic resistant bacteria and genes: Unveiling the jigsaw pieces of a one health problem. *Pathogens*, *9*(6), 497.

NPC. (2006). *Standard methods for the examination of dairy products*. National Pasteurized Milk Company.

Okareh, O. T., et al. (2015). The role of mobile genetic elements in antibiotic resistance. *Clinical Microbiology Reviews*, *28*(3), 637-654. https://doi.org/10.1128/CMR.00179-14

Okeke, I. N., et al. (2019). Antibiotic resistance in Nigeria: A review. *International Journal of Antimicrobial Agents*, 53(3), 328-334.

Okeke, I. N., Laxminarayan, R., & Bhutta, Z. A. (2019). Antimicrobial resistance in developing countries: A review. *Nature Reviews Microbiology, 17*(1), 75-85.

Opintan, J. A., et al. (2015). Transfer of resistance genes during food processing: Implications for public health. *Foodborne Pathogens and Disease*, *12*(6), 524-530. https://doi.org/10.1089/fpd.2015.1921

Oranusi, U. S., Adebayo, A. A., & Nwafor, P. (2011). Ready-to-eat foods: A health hazard in Nigeria. *Nigerian Journal of Microbiology, 25*(1), 1973-1980.

Osek, J., Wieczorek, K., Nowaczek, A., Marek, A., Stępień-Pyśniak, D., Dec, M., & Urban-Chmiel, R. (2022). Antibiotic Resistance in Bacteria—A Review. *Antibiotics*, 11. https://doi.org/10.3390/antibiotics11081079.

Osterblad, M., Laitinen, S., & Ruutu, P. (2019). The presence of antimicrobial-resistant bacteria in vegetables: Implications for food safety. *Foodborne Pathogens and Disease, 16*(4), 239-245.

Pal, D., et al. (2020). The role of food in the transmission of antibiotic-resistant E. coli. *Foodborne Pathogens and Disease*, 17(7), 435-445.

Pal, M., Kerorsa, G. B., Marami, L. M., and Kandi, V. (2020). Epidemiology, pathogenicity, animal infections, antibiotic resistance, public health significance, and economic impact of staphylococcus aureus: a comprehensive review. *American Journal of Public Health Research*, *8*(1), 14-21.

Paul, M., et al. (2018). National action plans for antimicrobial resistance: A global overview. *Antimicrobial Resistance & Infection Control*, *7*, 76.

Pesavento, G., et al. (2014). Antibiotic resistance in foodborne pathogens: A review. *International Journal of Food Microbiology*, *173*,

15-21. https://doi.org/10.1016/j.ijfoodmicro.2014.01.013.
Peterson, J. A., & Kaur, R. (2018). Shigella: Transmission and public health implications. *Journal of Infectious Diseases, 217*(2), 222-229.
Pinegar, K. N., & Cooke, R. A. (1985). The occurrence of antibiotic-resistant bacteria in confectionary products. *Journal of Food Protection, 48*(10), 894-898.
Praveenkumarreddy, G., Muthusamy, M., & Karthikeyan, K. (2020). Antibiotic resistance in foodborne pathogens isolated from doughnuts: A study. *International Journal of Food Microbiology, 328,* 108668.
Praveenkumarreddy, M., & et al. (2020). Monitoring antimicrobial resistance in food products: A necessity. *Journal of Food Protection*, *83*(9), 1525-1536. https://doi.org/10.4315/JFP-20-084
Rahman, M. M., et al. (2021). Isolation and characterization of bacteria from ready-to-eat foods. *Journal of Food Protection*, 84(2), 265-272.
Rahman, M. M., Nasrin, R., & Hossain, K. (2016). Antimicrobial resistance profiles of bacteria isolated from ready-to-eat food items in Nigeria. *Journal of Global Antimicrobial Resistance, 7,* 127-131.
Rahman, M., Alam, M. U., Luies, S. K., Kamal, A., Ferdous, S., Lin, A., and Ercumen, A. (2021). Contamination of fresh produce with antibiotic-resistant bacteria and associated risks to human health: A
scoping review. *International journal of environmental research and public health*, *19*(1), 360.
Reygaert, W. C. (2018). An overview of the antimicrobial resistance of Shigella. *Healthcare, 6*(4), 126.
Salam, M. A., Al-Amin, M. Y., Salam, M. T., Pawar, J. S., Akhter, N., Rabaan, A. A., and Alqumber, M. A. (2023, July). Antimicrobial resistance: a growing serious threat for global public health. In *Healthcare* (Vol. 11, No. 13, p. 1946). MDPI.
Salam, M. R., et al. (2023). Antibiotic resistance patterns in foodborne pathogens from ready-to-eat foods: Implications for public health. *Food Microbiology*, 102, 103865.
Sanford, L., Hernandez, A., Varela, M., Ojha, M., Parvathi, A., Stephen, J., Wenzel, N., Kumar, S., & Lekshmi, M. (2021). Bacterial Resistance to Antimicrobial Agents. *Antibiotics*, 10. https://doi.org/10.3390/antibiotics10050593.
Scardino, G., Bianchi, D., Razzuoli, E., Garcia-Vozmediano, A., Tramuta, C., Battistini, R., Orusa, R., Masotti, C., Brusa, B., Floris, I., Serracca, L., Musolino, N., & Martucci, F. (2025). Antibiotic Resistance in Lactic Acid Bacteria from Dairy Products in Northern Italy. *Antibiotics*, 14. https://doi.org/10.3390/antibiotics14040375.
Schoeder, J. S., Lammers, E. J., & Morgan, D. J. (2017). The impact of antibiotic resistance on meat and poultry: A review. *Foodborne Pathogens and Disease, 14*(8), 451-458.
Seabela, M. D. L. (2020). *Assessment of Food Safety Hazards among Day Care Centres in Mbombela, Republic of South Africa* (Master's thesis, University of Johannesburg (South Africa).
Seabela, P. (2020). Ready-to-eat food as a source of antimicrobial-resistant bacteria: A review. *African Journal of Food Science*, 14(9), 321-330.
Shaheen, N. R., Khan, M. N., & Shamsi, A. (2018). Staphylococcus aureus: A significant foodborne pathogen. *Journal of Food Protection, 81*(8), 1303-1312.
Stratev, D., & Odeyemi, O. A. (2016). Antibiotic resistance and public health: A global perspective. *Microbial Drug Resistance*, *22*(8), 748-758. https://doi.org/10.1089/mdr.2016.0121
Tadesse, D. A., et al. (2019). The healthcare burden of antibiotic-resistant infections: Implications for policy. *Journal of Global Antimicrobial Resistance*, *18*, 125-130. https://doi.org/10.1016/j.jgar.2019.06.008
Tellevik, I. K., et al. (2016). Contamination of the food chain with antibiotic-resistant bacteria: Public health implications. *International Journal of Food Microbiology*, *217*, 101-109. https://doi.org/10.1016/j.ijfoodmicro.2015.10.011.
Uddin, M. N., et al. (2017). The International Health Regulations and antimicrobial resistance: A framework for global health security. *Global Health Action*, *10*(1), 1367342.
Varkey, J., & Canet, C. (2012). Street foods: Global consumption patterns and implications for public health. *International Journal of Environmental Health Research, 22*(1), 24-34.
Weinstein, M. P., & Lewis, J. S. (2020). *The role of laboratory testing in the management of infections*. *Clinical Microbiology Reviews*, *33*(1), e00020-19.
Weinstein, M. P., & Lewis, S. (2020). The impact of antimicrobial resistance on public health: An overview. *Infectious Disease Clinics of North America, 34*(2), 217-225.
WHO. (2017). Antimicrobial resistance: Global report on surveillance. World Health Organization.
WHO. (2018). Global antimicrobial resistance surveillance system: Manual for early implementation. World Health Organization.
WHO. (2020). Global action plan on antimicrobial resistance. World Health Organization.
World Health Organization (WHO). (2018). *Global action plan on antimicrobial resistance.* World Health Organization.
Ye, J., et al. (2018). The role of wildlife in the spread of antibiotic-resistant bacteria. *Microbial Ecology*, *76*(4), 942-952. https://doi.org/10.1007/s00248-018-1153-5
Yeleliere, M. M., et al. (2017). The impact of antibiotic-resistant bacteria on public health. *Antibiotics*, *6*(2), 26.