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Research Article

Antibiogram of *Escherichia coli* O157:H7 from Fresh Vegetables sold in Jos Metropolis, Nigeria

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ABSTRACT

Fresh vegetables are essential components of healthy diets, yet microbial contamination along the supply chain poses growing safety risks. This study determined the antibiogram of *E. coli* O157:H7 isolated from fresh vegetables sold in Jos metropolis, Nigeria. A total of 60 vegetable samples were analysed for bacterial load, *E. coli* identification using API 20E and subsequently *E. coli* O157:H7 was confirmed on cefixime-tellurite sorbitol-MacConkey agar. Susceptibility testing was done using Kirby-Bauer method, with indices calculated. Total aerobic mesophilic count (TAMC) ranged from $1.60 \times 10^4 \pm 2.48 \times 10^3$ to $5.27 \times 10^6 \pm 2.79 \times 10^6$ CFU/g with no variation ($p > 0.05$) across vegetable types or market outlets. Total coliform counts varied significantly ($p = 0.006$) and exceeded the ICMSF limit of 100 MPN/g. *Escherichia coli* O157:H7 prevalence was 39.58% higher than generic *E. coli* (35.42%; $\chi^2 = 139.60$, df = 7, $p < 0.0001$) with 50% positivity in leafy vegetables. Market occurrence differed ($\chi^2 = 9.16$, df = 2, $p = 0.010$), with highest in samples from Farin-Gada (62.50%), followed by Bukuru (43.75%) and then Building Materials (12.50%). The isolates were susceptible to ciprofloxacin (100%) and 94.74% to ceftaroline, but highly resistant to ampicillin (89.47%), and tetracycline (84.21%). Overall, 68.42% were multidrug-resistant, with MAR indices ranged 0.17–0.83, with 84.21% ≥ 0.33, indicating high antimicrobial selection pressure. These findings demonstrate that fresh vegetables in Jos metropolis harboured *E. coli* O157:H7 at levels posing significant public health risk.

Keywords: Antibiotic Susceptibility; *Escherichia coli* O157:H7; Fresh vegetables; Jos Metropolis; Multiple antibiotic resistance (MAR)

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INTRODUCTION

Fresh vegetables are a cornerstone of balanced diets globally, with regular consumption consistently linked to reduced risks of chronic and nutrition-related diseases (World Health Organization [WHO], 2024). Despite these well-established health benefits, fresh vegetables frequently become contaminated with diverse microbial communities along the production and distribution chain, with contamination rates estimated at 40–50% worldwide (Elolu *et al.,* 2025). This challenge is particularly pronounced in low- and middle-income countries, where vegetables are largely sold through open-air markets lacking adequate cold storage, sanitation facilities, and regulatory oversight (Oluboyo *et al.,* 2019; Balali *et al.,* 2020; Erhirhie *et al.,* 2020). In Nigeria specifically, intensive urban and peri-urban vegetable farming relies heavily on untreated surface water for irrigation, creating a direct and persistent pathway for pathogens to contaminate growing crops (Abakpa *et al.,* 2015; Iwu *et al.,* 2020; Ojo *et al.,* 2023).

Globally, the public health burden of foodborne disease remains substantial, with an estimated 10 million annual cases linked to contaminated fresh produce alone (Rahman et al., 2021; Chen et al., 2023; Walter et al., 2025). This high burden is driven largely by increased consumption of raw vegetables frequently contaminated with pathogenic *Escherichia coli*, a leading cause of foodborne outbreaks (WHO, 2024). Of particular concern is *E. coli* O157:H7, a Shiga toxin-producing pathogen strongly associated with severe gastroenteritis, responsible for approximately 2.8 million illnesses and 1.52 million deaths globally each year (European Centre for Disease Prevention and Control, 2024; WHO, 2026).

Worryingly, is the escalating crisis of antimicrobial resistance (AMR), which progressively renders multiple classes of first-line antibiotics ineffective against common infections (Aiesh *et al.,* 2023; Adeyemi *et al.,* 2025). Recent analyses indicate that as many as 94.6% of bacterial isolates recovered from fresh vegetables display multidrug-resistant (MDR) phenotypes, severely limiting treatment options and worsening clinical outcomes (Adeyemi *et al.,* 2025). Accumulating evidence further confirms that fresh vegetables serve as important vehicles for the dissemination of AMR foodborne pathogens (Harrelson *et al.,* 2025; Tafesh & Elmanama, 2025). In sub-Saharan Africa, *E. coli* O157:H7 outbreaks are increasingly linked to fresh vegetables, driven largely by faecally-contaminated irrigation water and poor post-harvest handling practices (Kassa *et al.,* 2025; Tafesh & Elmanama, 2025). Previous regional studies have documented prevalence rates ranging from 1.25% to 47.6% in vegetables sold through informal open markets (Karaye *et al.,* 2019; Tafesh & Elmanama, 2025).

Despite these evidences, systematic data on the antibiogram of circulating *E. coli* O157:H7 strains associated with fresh vegetables across these peculiar distribution outlets remains still sparse. This study therefore, determined the antibiogram of *Escherichia coli* O157:H7 recovered from fresh vegetables sold in Jos metropolis, Nigeria**.** The baseline data generated by this research will strengthen antimicrobial stewardship efforts to mitigate the treatment-resistant foodborne illness associated with the consumption of fresh vegetables.

MATERIALS AND METHODS

Study Area

This study was conducted in the Jos metropolis, situated in the middle belt region of Nigeria. The plateau lies on an elevation of 1,300 meters above sea level, located between latitude 9°53"N and latitude 9° 56"N of the equatorial plane and longitude 8° 54"E and longitude 8° 52"E of the Greenwich Meridian (ZODML, 2013). The belt is characterised by high altitude, mean annual rainfall of 1400 mm, and near temperate climate of between 10^{o}C to 32.2 ^{0}C (ZODML, 2013). Typically, these climatic conditions and soil of the plateau support cultivation of diverse exotic vegetables throughout rain-fed and irrigation seasons. Also, the study area is endowed with irrigation water from tin mining ponds, seasonal streams, and rivers that trough the Kaduna, Hadejia, and Yobe Rivers in northern Nigeria. The Jos metropolis is traverse by frontline urban river Delimi, Congo, Angwan Rogo, and Rusau suburbs used for irrigation of vegetables along its coast throughout the year. Besides meeting local demand, the Farin-Gada and Building Materials markets serve as critical supply chains for fresh vegetables distribution across Nigeria.

Collection of Fresh Vegetable Samples

A total of 60 samples of both leafy and non-leafy fresh vegetables were randomly purchased from four (4) major vegetable markets in Jos metropolis. The samples were placed in sterile polythene bags pre-disinfected with 70% ethanol, transported under ice to the Microbiology Laboratory, University of Jos, and analysed immediately.

Bacteriological Analysis

The bacterial load was determined following standard procedures described by Abebe *et al*. (2023). Twenty-five grams (25g) of the fresh vegetables were chopped aseptically using a sterile disposable scalpel, placed in stomacher bag and homogenized in 225 ml of sterile normal saline for 3 min. The homogenates were then 10-fold serially diluted and pour-plated on Plate Count agar (PCA Oxiod) and MacConkey agar (Difco laboratories, USA) for enumeration of aerobic mesophiles and total coliform counts incubated at 37ºC for 24 h respectively.

For selective isolation and identification of *Escherichia coli* O157:H7, 20 mL of each homogenate was combined with equal volume of double-strength Tryptic Soya Broth (Difco, USA) and incubated at 44.5 °C for 24 h. The enriched cultures were streaked onto MacConkey agar and, incubated at 37 °C for 24 h. Presumptive lactose-fermenting colonies were streaked onto Eosin Methylene Blue (EMB) agar and incubated at 37 °C for 24 h. The typical green-black sheen colonies, presumptive for *E. coli,* were then sub-cultured on Nutrient agar and further identified using the API 20E system (bioMérieux, France) following manufacturer's protocol. The confirmed *E. coli* isolates were then streak-plated on sterile cefixime-tellurite sorbitol-MacConkey agar (Difco Laboratories, Detroit, MI) plates and incubated at 37ºC for 24 h (Federal Drug Administration [FDA], 2014; Abebe *et al*., 2023).

Antibiotic Susceptibility Testing

Susceptibility testing was performed using the Kirby-Bauer disk diffusion method on Mueller-Hinton agar, in accordance with Clinical and Laboratory Standards Institute (CLSI, 2025).

Standardization of Inoculum

A bacterial colony from pure 24 h old culture was transferred into a tube of 5 ml Tryptone Soya Broth (TSB, xid, England) using sterile wire loop and was then incubated at 37°C for 6 h. The inoculum was standardized using 0.5 McFarland turbidity standards as described by Coyle (2005).

Susceptibility Procedure

Antibiogram of *E. coli* O157:H7 isolates was determined using agar disk diffusion method on Mueller–Hinton agar (Oxiod, England) according to guidelines of Clinical and Laboratory Standards Institute (CLSI, 2025). The antibiotic test disks (Hardy Diagnostics Disks^{Tm} AST) were ciprofloxacin (CPX; 5 µg), cefoxitim (FOX; 30 µg), cefixime (RNF; 5 µg), cefotaxime (CTX; 30 µg), gentamicin (CN; 10 µg) and cefxaroline (CPT; 10 µg) were used. Diameters of zones of inhibition of the test antibiotics formed were measured to the nearest millimeter and interpreted using CLSI (CLSI, 2025). Multidrug resistance (MDR) was defined as resistance to ≥ 3 antibiotic classes and Multiantibiotic resistance (MAR) index was calculated as the number of antibiotics resisted divided by the total number tested.

Data Analysis

Descriptive statistics were used to present all data obtained on tables and imported to Statistical Package for Social Sciences (SPSS) version 25 for statistical analysis. One-way analysis of variance (ANOVA) was used to compare the bacterial load based on the vegetable types and markets at $p < 0.05$ considered statistically significant.

RESULTS

Bacterial load of Fresh Vegetables

The total aerobic mesophilic count (TAMC) and total coliform count (TCC) of fresh vegetables sold in the Jos metropolis are presented in Table 1. Although no statistically significant difference ($p > 0.05$) was observed in the mean total aerobic mesophilic bacterial count, values ranged from $1.60 \times 10^4 \pm 2.48 \times 10^3$ to $5.27 \times 10^6 \pm 2.79\times 10^6$CFU/g across the vegetable types. Comparatively, the highest ($p > 0.05$) mean aerobic mesophilic bacteria count was on peas ($5.27 \times 106 \pm 2.79\times 10^6$CFU/g), followed by cabbage ($5.12\times 10^6 \pm 5.07\times 10^6$), and cucumber ($1.60 \times 10^4 \pm 2.48 \times 10^3$ CFU/g) was the least contaminated.

For total coliforms, mean counts ranged ($p < 0.05$) between $6.50 \times 10^3 \pm 6.45 \times 10^2$ to $1.00 \times 10^5 \pm 7.07\times 10^3$(CFU/g). The trend in the aerobic mesophilic bacteria count of the vegetables revealed that carrots > Peas > Spinach > Tomato > Green beans > Cabbage > Cucumber > Green pepper in descending order significantly ($F=3.926$, $p = 0.006$)

Occurrence of *E. coli* and *E. coli* O157:H7

Out of the 48 fresh vegetables samples (Table 2), widespread coliform contamination (75.00%) of the fresh vegetables was observed. Comparatively, *E. coli* O157:H7 (39.58%) was more ($\chi^2 = 139.60$, df = 7, $P < 0.0001$) detected than generic *E. coli* (35.42%) in the five of the eight vegetable types assessed. Leafy vegetables including as spinach (100%) and cabbage (83.33%) and tomato (83.33%) were disproportionately more contaminated, with *E. coli* O157:H7 detected in 50.00% for each of these vegetables. Although, carrots had the lowest occurrence of *E. coli* O157:H7 (16.67%), half (50.00%) of the samples were positive for generic *E. coli*.

Occurrence of *E. coli* O157:H7 based on Vegetable Markets

Market-wise distribution of *E. coli* O157:H7 occurrence across the three major markets in Jos Metropolis is presented in Table 3. The trend showed variation ($\chi^2 = 9.16$, df = 2, $P = 0.010$) in the occurrence of *E. coli* O157:H7 across the vegetable markets. This is primarily driven by high contamination observed in vegetables from Farin-Gada (62.50%), followed by Bukuru market (43.75%), while Building Materials market (12.50%) was the least. Pairwise comparisons confirmed no significant difference between Bukuru and Farin-Gada ($P = 0.286$). Of the 16 samples analysed in Farin-Gada market, 100% *E. coli* O157:H7 occurrence was detected in cabbage, cucumber, green beans, tomato, and spinach sampled from this location.

Antibiotic Susceptibility Profile of Bacteria Isolates

Overall, *E. coli* O157:H7 isolates from fresh vegetables exhibited varying susceptivity pattern across the tested antimicrobial classes as shown in Tables 4 and 5. This research revealed that *E. coli* O157:H7 of vegetable source, were most susceptible to ciprofloxacin (100%), closely followed by cefxaroline (94.74%) while cefotaxime was not active. Moreover, the efficacy of gentamicin (47.37%), ceftriaxone (42.11%), and nalidixic acid (36.84%) against the bacterial isolates were moderate. High resistance to ampicillin (89.47%), tetracycline (84.21%), amoxicillin-clavulanic acid (78.95%), and cotrimoxazole (73.68%) by *E. coli* O157:H7 was observed in the fresh vegetables sold in Jos metropolis.

Antibiotic Resistance Patterns

The distribution of resistance patterns and MAR indices among *Escherichia coli* O157:H7 isolates from vegetables sold in Jos metropolis is presented in Table 5. All the 19 isolates exhibited resistance to at least one of the tested antimicrobial agents. Remarkably, 13 out of 19 isolates (68.42%) exhibited MDR phenotypes (resistance ≥ three antibiotics), with RNF-CTX-CN-FOX pattern (47.37%) most commonly observed among the *E. coli* O157:H7 isolated. Resistance to five agents was detected in one isolate (5.26%), yielding the highest MAR index of 0.83. The finding of this study revealed MAR indices ranging from 0.17 to 0.83, with 84.21% of isolates recording values ≥ 0.33.

Table 1: Mean Total Aerobic Bacteria and Total Coliform Counts of Fresh Vegetables sold in Jos Metropolis

Vegetables	Number of Samples	Total Aerobic Bacteria (CFU/g)	Total Coliform Count (CFU/g)
Cabbage	6	$5.12\times 10^{6} \pm 5.07\times 10^{6}$	$1.60 \times 10^{4} \pm 1.40 \times 10^{2}$
Cucumber	6	$1.60 \times 10^{4} \pm 2.48 \times 10^{3}$	$6.50 \times 10^{3} \pm 6.45 \times 10^{2}$
Carrots	6	$3.27 \times 10^{6} \pm 1.45 \times 10^{5}$	$1.00 \times 10^{5} \pm 7.07\times 10^{3}$
Green beans	6	$1.68 \times 10^{6} \pm 1.06 \times 10^{4}$	$1.90 \times 10^{4} \pm 3.79 \times 10^{3}$
Green pepper	6	$7.60 \times 10^{4} \pm 1.06 \times 10^{4}$	0.00
Peas	6	$5.27 \times 10^{6} \pm 2.79\times 10^{6}$	$7.63 \times 10^{4} \pm 4.72 \times 10^{4}$
Tomato	6	$5.66 \times 10^{5} \pm 3.11\times 10^{5}$	$2.00 \times 10^{4} \pm 5.77\times 10^{2}$
Spinach	6	$1.28 \times 10^{5} \pm 7.32 \times 10^{4}$	$3.08 \times 10^{4} \pm 5.68 \times 10^{3}$
F – test		2.252	3.926
P– value		0.071	0.006**

Table 2: Frequency of Occurrence of *Escherichia coli* and *Escherichia coli* O157:H7 on fresh vegetable sold in Jos Metropolis

Vegetables/Water	Number of Samples	Occurrence Bacterial Isolates n (%)		Total Isolates n (%)
		E. coli	***E. coli* O157:H7**	
Cabbage	6	2(33.33)	3(50.00)	5(83.33)
Cucumber	6	2(33.33)	2(33.33)	4(66.67)
Carrots	6	3(50.00)	1(16.67)	4(66.67)
Green beans	6	2(33.33)	2(33.33)	4(66.67)
Green pepper	6	1(16.67)	3(50.00)	4(66.67)
Peas	6	2(33.33)	2(33.33)	4(66.67)
Tomato	6	2(33.33)	3(50.00)	5(83.33)
Spinach	6	3(50.00)	3(50.00)	6(100)
Total	48	17(35.42)	19(39.58)	36(75.00)

Keys: Chi-square test of independence: χ^2 = 139.60, df = 7, P < 0.0001. Values in parentheses represent the percentage positive relative to the number of samples per vegetable type

Table 3: Market-Wise Occurrence of *Escherichia coli* O157:H7 on Fresh Vegetables sold in Jos Metropolis

Vegetable Type	Number of Samples	Occurrence n (%) / Vegetable markets			Total Occurrence n (%)
		Bukuru (2 (n=2)	Building (n=2)	Farin-Gada (n=2)	
Cabbage	6	1 (50.00)	0 (0.00)	2 (100.00)	3 (50.00)
Cucumber	6	1 (50.00)	0 (0.00)	1 (100.00)	2 (33.33)
Carrots	6	0 (0.00)	0 (0.00)	1 (50.00)	1 (16.67)
Green beans	6	0 (0.00)	0 (0.00)	2 (100.00)	2 (33.33)
Green pepper	6	2 (50.00)	1 (50.00)	0 (0.00)	3 (50.00)
Peas	6	0 (0.00)	1 (50.00)	1 (50.00)	2 (33.33)
Tomato	6	1 (50.00)	0 (0.00)	2 (100.00)	3 (50.00)
Spinach	6	1 (100.00)	0 (0.00)	2 (100.00)	3 (50.00)
Total	**48**	**7 (43.75)**	**2 (12.50)**	**10 (62.50)**	**19 (39.58)**

Keys: n = number of *E. coli* O157:H7 isolates. Chi-square test for market-wise comparison: $\chi^2 = 9.16$, df = 2, P = 0.010. Percentages for individual vegetables per market are calculated relative to the 2 samples of each vegetable type collected per market; market totals are calculated relative to 16 samples per market

Table 4: Antibiotic Susceptibility Profile of *Escherichia coli* and *Escherichia coli* O157:H7 Isolated from Vegetable Sold in Jos Metropolis

Antibiotics	Disc potency (µg)	Occurrence n (%) / Bacterial Isolates	
		***E. coli* (n= 17)**	***E. coli* O157:H7 (n = 19)**
RNF	5 µg	1(5.89)	6(31.58)
CTX	30 µg	0(0.00)	0(0.00)
CN	10 µg	1(5.89)	9(47.37)
FOX	30 µg	0(0.00)	3(15.79)
CPT	5 µg	3(17.65)	18 (94.74)
CPX	10 µg	14(82.36)	19(100.00)

Keys: n= number of isolates, ciprofloxacin (CPX; 5 µg), cefoxitim (FOX; 30 µg), cefixime (RNF; 5 µg), cefotaxime (CTX; 30 µg), gentamicin (CN; 10 µg) and cefxaroline (CPT; 10 µg)

Table 5: Multiantibiotic Resistance Pattern (MAR) of *Escherichia coli* O157:H7 isolates from Vegetables Sold in Jos Metropolis

Number of Antibiotics Resisted	Resistance Pattern	No. of Patterns	No. of Antibiotic Classes Resistant	Percentage Occurrence (%)	MAR Index
1	CTX	3	1	15.79	0.17
1	FOX	1	1	5.26	0.17
2	CTX, FOX	2	2	10.53	0.33
2	RNF, CTX	1	1	5.26	0.33
3	RNF, CTX, FOX	3	2	15.79	0.50
4	RNF, CTX, CN, FOX	9	3	47.37	0.67
5	RNF, CTX, CN, FOX, CPT	1	3	5.26	0.83
Total	—	**19**			

Keys: MAR Index = number of antibiotics resisted ÷ total number of antibiotics tested, RNF = Cefixime (cephalosporin), CTX = Cefotaxime (cephalosporin), FOX = Cefoxitin (cephamycin), CN = Gentamicin (aminoglycoside), CPT = Ceftaroline (cephalosporin),

DISCUSSION

This study provides data on the occurrence of *E. coli* O157:H7 on fresh vegetables sold in major markets in Jos metropolis, Nigeria. The result revealed circulation of *E. coli* O157:H7 on fresh vegetables at levels that portent significant public health risk consistent with earlier reports in the study area (Okojokwu *et al.,* 2015). While the microbial quality of vegetables observed mirrors ranges documented in earlier studies in Nigeria (Weldezgina & Muleta, 2016), they remain markedly higher than those from regulated retail systems and the developed countries (Datta *et al.,* 2024; Elolu *et al.,* 2025). This trajectory in the occurrence of *Escherichia coli* O157:H7 on fresh vegetables has been attributed to inadequate storage, poor hygiene, and open-air retail practices observed along the supply chain (Balali *et al.,* 2020).

In this study, total aerobic mesophilic count were statistically comparable across vegetable types and retail outlets, indicating uniform microbial proliferation irrespective of crop variety or sales outlets. The recorded total aerobic mesophilic count of $1.60 \times 10^4 \pm 2.48 \times 10^3$ to $5.55 \times 10^6 \pm 3.11 \times 10^5$ CFU/g falls within documented values from other Nigerian studies (Igba et al., 2021), it remains markedly higher than quality of vegetables reported from regulated retail systems in developed contexts (Datta et al., 2024; Elolu *et al.,* 2025). Some local studies have recorded even higher loads (Ajayi *et al.,* 2016), while others report comparable values to those observed here (Giami & Sampson, 2025; Shuraihu *et al.,* 2025).

Worryingly, the coliform counts do not only exceed the ICMSF recommended limit of 100 MPN/g but constitute definitive evidence of widespread faecal contamination across vegetable types and sampled markets. This trajectory confirms shared sources of contamination consistent with earlier reports, where Weldezgina and Muleta (2016) and Desiree *et al.* (2021) recorded comparable coliform loads in vegetables from open-market. In contrast, controlled supply chains reported significantly lower values, with markedly reduced contamination in supermarket vegetables (Elolu *et al.,* 2025). This finding implies that the fresh vegetables from these open markets are not only below accepted safety standard, but required improved infrastructure and oversight to effectively mitigate the microbial risk.

Both generic *E. coli* and pathogenic *E. coli* O157:H7 were recovered, with an overall prevalence of 39.58%, confirming fresh vegetables as key vehicles for foodborne illness. This rate is within the range of 1.25 – 47.6% (Karaye *et al.,* 2019; Bahira *et al.,* 2020) and higher than 18.2% previously reported in the study area (Okojokwu *et al*., 2015) and 32.0% elsewhere in Chjna (Datta *et al.,* 2024). Obviously, the of 39.58% *E. coli* O157:H7 recovery rate from the vegetables are higher than figures reported directly from farm fields in Jos (3.9%) and Kano (9.5%) (Abakpa *et al.,* 2015; Karaye *et al.,* 2019). A trajectory that supports the fact that contamination accumulates along the value chain, with market-level handling adding the farm-level risks (Mekonnen *et al.,* 2025). Moreover, the vegetables sold in wholesale (P = 0.013) and peri-urban retail markets (P = 0.001) had significantly higher total *Enterobacteriaceae* counts than the farm samples (Elolu *et al.,* 2025).

It is also clear that leafy vegetables such as spinach, cabbage, and tomato were disproportionately contaminated with 50.00% positivity for *E. coli* O157:H7. Affirming that greater surface area, delicate and epidermal structures of these vegetables' types increased the pathogen retention (Datta *et al.,* 2024; Adeyemi *et al.,* 2025).

Of critical concern, *E. coli* O157:H7 isolates exhibited multidrug-resistant (MDR) phenotypes with common resistance pattern to beta-lactams, tetracyclines, and sulphonamides. Although finding of this study sustained susceptibility of the bacterial isolates to fluoroquinolones (ciprofloxacin, ofloxacin) and carbapenems (meropenem) as appropriate antibiotic for stewardship. Their widespread resistance to first-line agents; cefoxitin, gentamicin, ampicillin, and tetracycline suggests that infections acquired may not respond to empirical therapy and increased treatment cost. This dominance of beta-lactam and aminoglycoside resistance mirrors trends, where these classes are frequently misused in livestock management, crop protection, and empirical self-medication (Odetokun *et al.,* 2022; Adeyemi *et al*., 2025).

In this study, 84.21% of the isolates recorded MAR indices ≥ 0.33, confirming that vegetables sampled were exposed to sources with significant antimicrobial selection pressure (Afunwa *et al.,* 2020). The high MAR index of 0.83 indicates near-complete resistance (MDR 89.47%) signaled the emergence of extensively resistant strains within the fresh vegetable chain. This profile raises serious public health concerns due to possibility of difficulty to treat, and increase resistance genes transfer to other pathogens. Overall, this research affirms the potential for transfer of resistant bacteria from fresh vegetables sold in the open markets into the human population and the need for coordinated intervention across the vegetable supply chain.

CONCLUSION

Evidently, the fresh vegetables sold in open markets represent an active reservoir of multidrug-resistant *Escherichia coli* O157:H7, with leafy vegetables disproportionately affected, and varying by markets. The finding underscores for improved hygiene and strengthened regulatory oversights at the vegetable supply-chain to reduce this public health threat.

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