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Insect-Mediated Contamination of Fresh Vegetables and the Environmental Dissemination of Antimicrobial Resistance in Urban Markets of Ibadan, Nigeria

Awe, Omolara, Oluwafunmilola[1*]; Awe, Mercy, Toluwani[2]

[1]Department of Biology, Adeyemi Federal University of Education, Ondo, Ondo State
[2]Department of Microbiology, Federal University of Technology, Akure, Ondo State

Corresponding Author: Awe, Omolara, Oluwafunmilola[1*]

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Abstract: This study investigated the role of synanthropic insects—such as houseflies, cockroaches, ants, and beetles—as mechanical vectors for antibiotic-resistant enteric bacteria in six open vegetable markets within Ibadan, Nigeria. While vegetables are vital to human diets, open markets in developing countries often lack the infrastructure required for proper food safety and environmental sanitation, increasing the risk of microbial contamination. A cross-sectional study was conducted to assess the diversity and abundance of these insect vectors in vegetable retail environments. Researchers recorded a total of 3,274 insects, categorized into the orders Diptera, Blattodea, Hymenoptera, and Coleoptera. Among these, houseflies (Musca domestica) were the most abundant (27.5%), followed by cockroaches (26.8%), ants (23.8%), and beetles (21.9%). Bodija Market recorded the highest insect activity (676 individuals), while Sango Market recorded the lowest (425 individuals). Statistical analysis indicated relatively similar community structures across all sites, with no significant differences in group distribution among the markets. Shannon–Wiener diversity indices ranged from 1.365 to 1.386, indicating relatively similar insect community structures across markets. Chi-square analysis revealed no statistically significant differences in insect group distribution among markets ($\chi^2 = 13.55$, $p > 0.05$). The widespread presence of these insects in retail settings highlights a significant pathway for the dissemination of antimicrobial resistance within urban food systems. To mitigate these risks and safeguard public health, the study recommends enhancing environmental sanitation, implementing effective waste management and vector control strategies, and promoting public health education in open markets.

Keywords: *Antibiotic Resistance, Insect Vectors, Vegetable Contamination, Mechanical Transmission, Food Safety, Ibadan.*

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I. INTRODUCTION

Fresh vegetables play an important role in human nutrition, providing essential vitamins, minerals, and dietary fiber that support health. In many urban centers in developing countries, including Ibadan metropolis in southwestern Nigeria, vegetables are widely consumed either raw or with minimal processing. While this dietary practice promotes healthy eating, it also increases the risk of exposure to microbial contaminants, particularly when vegetables are displayed and sold in open markets where sanitary conditions are often inadequate (Olanbiwoninu and Olanrewaju, 2024). Open vegetable markets create environments that favor contamination from multiple sources. Produce is commonly displayed without protective covering and is exposed to dust, wastewater, repeated human handling, and animal activity. Such conditions facilitate the transfer and persistence of microorganisms on vegetable surfaces.

Several studies conducted in Nigerian and other African urban markets have reported the isolation of enteric bacteria from fresh produce, including *Escherichia coli*, *Salmonella* spp., *Klebsiella* spp., and *Staphylococcus aureus*, with many isolates exhibiting resistance to commonly used antibiotics (Onwugamba *et al.*, 2020). Insects are especially abundant in open market environments and are strongly attracted to vegetable stalls by organic

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matter, moisture, and food residues. Common synanthropic insects such as houseflies *(Musca domestica)*, cockroaches (*Periplaneta* spp. and *Blattella* spp.), ants, and beetles move freely between refuse dumps, sewage-contaminated areas, and exposed food items. Their frequent contact with contaminated substrates positions them as potential carriers of microorganisms of public health significance (Bawin *et al.*, 2021).

These insects function primarily as mechanical vectors, acquiring microorganisms on their body surfaces or through feeding activities and subsequently depositing them onto exposed vegetables. Their mobility, feeding behavior, and close association with human environments enhance their capacity to disseminate enteric bacteria within market settings. Although insects do not support the biological development of most enteric pathogens, their role in passive transmission remains epidemiologically important, particularly in densely populated urban markets where produce is exposed for extended periods (Fotedar *et al.*, 2020).

Antimicrobial resistance (AMR) has emerged as a global health threat affecting both clinical and environmental sectors. Increasing evidence indicates that food systems, particularly fresh vegetables sold in open markets, can serve as reservoirs for antibiotic-resistant bacteria. In many developing urban centers, vegetables are displayed openly, exposing them to environmental contaminants and insect vectors. In recent years, the emergence of antibiotic-resistant bacteria has added a critical dimension to food safety concerns. Resistant enteric bacteria are increasingly detected in environmental reservoirs, including food, water, and waste, posing serious public health challenges. Studies have shown that fresh vegetables sold in urban markets can harbor multidrug-resistant bacteria, suggesting that food systems may contribute to the environmental circulation of antimicrobial resistance beyond clinical settings (Olanbiwoninu and Olanrewaju, 2024).

The efficiency of insects as mechanical vectors is strongly influenced by their morphology and behavior. For example, the sponging mouthparts and densely haired body surfaces of houseflies enhance microbial adherence, while the cryptic habits and wide foraging range of cockroaches allow them to transport microorganisms across multiple environments over extended periods (Fotedar *et al.*, 2020;). Although insects do not contribute to the genetic development of antimicrobial resistance, their ability to transport resistant bacteria across ecological niches represents a potential pathway for resistance dissemination within food systems. (Onwugamba *et al*., 2020).

Despite growing awareness of AMR, limited studies have integrated entomological and microbiological assessments within Nigerian vegetable markets. This study addresses this gap. The aim of this study was to assess the role of common insect vectors in the transmission of antibiotic-resistant enteric bacteria to fresh vegetables sold in selected urban markets within Ibadan metropolis, Nigeria. The study focused on collection and identification of insect species associated with fresh vegetable displays in selected markets within Ibadan metropolis.

II. MATERIALS AND METHODS

➢ *Study Area*

The study was conducted in Ibadan metropolis, Oyo State, Nigeria. Ibadan lies between latitude 7°20′ and 7°40′ N and longitude 3°50′ and 4°10′ E. It is one of the largest metropolitan areas in Nigeria and serves as a major commercial hub for agricultural produce, including fresh vegetables, which are supplied from surrounding rural farming communities and distributed through numerous open markets across the city. Mean annual rainfall ranges between 1,200 and 1,500 mm, with average temperatures varying from approximately 22°C to 34 °C. These climatic conditions are favorable for the proliferation of synanthropic insects and support continuous insect activity throughout most of the year. Selected markets within the metropolis serve as major points for the retail of fresh vegetables such as leafy greens, tomatoes, peppers, and cucumbers. The combination of favorable climatic conditions, open market structures, and high insect density makes Ibadan metropolis an appropriate setting for investigating the role of insect vectors in the contamination of fresh vegetables with antibiotic-resistant enteric bacteria.

➢ *Sample Collection*

Insects and vegetables were collected concurrently from selected markets (Oje, Oritamerin, Beere, Sango, Mokola and Bodija). Vegetable samples were randomly collected from different vendors to minimize sampling bias and to reflect variability in handling and display practices within the market. Insect sampling was conducted concurrently at the same vegetable stalls to allow for direct comparison between bacterial isolates obtained from insects and those recovered from vegetables. Insects were collected from areas immediately surrounding vegetable displays using a combination of hand collection, sweep nets, and sticky traps, depending on the insect type and market layout.

Sampling was carried out during peak market hours when human activity and insect movement were highest, thereby increasing the likelihood of capturing representative insect–vegetable interactions. The coordinated sampling of insects and vegetables within the same environments was designed to support assessment of the potential role of insect vectors in the dissemination of antibiotic-resistant enteric bacteria in urban vegetable markets.

➢ *Data Analysis*

Data obtained from entomological and microbiological analyses were entered into a spreadsheet and checked for accuracy prior to analysis. Descriptive statistics were used to summarize insect diversity, frequency, and distribution across the selected markets. The data analysis approach was designed to support assessment of the potential role of insect vectors as mechanical carriers of antibiotic-resistant enteric bacteria in urban vegetable market environments.

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III. RESULTS

➢ *Total Insect Specimens*

- *Insect Diversity and Distribution Across Selected Markets*

A total of 3,274 insect vectors were recorded from vegetable retail environments across six major markets in Ibadan, Nigeria: Oje Market, Oritamerin Market, Beere Market, Sango Market, Mokola Market, and Bodija Market.(Table 1, Fig 1)

Table 1 Distribution of Insect Vectors Across Selected Markets in Ibadan

Insect	Oje	Oritamerin	Beere	Sango	Mokola	Bodija	Total
Houseflies	120	163	141	110	165	202	901
Cockroaches	112	157	140	107	163	199	878
Ants	107	141	115	107	152	156	778
Beetles	102	133	113	101	149	119	717
Total per Market	441	594	509	425	629	676	3274

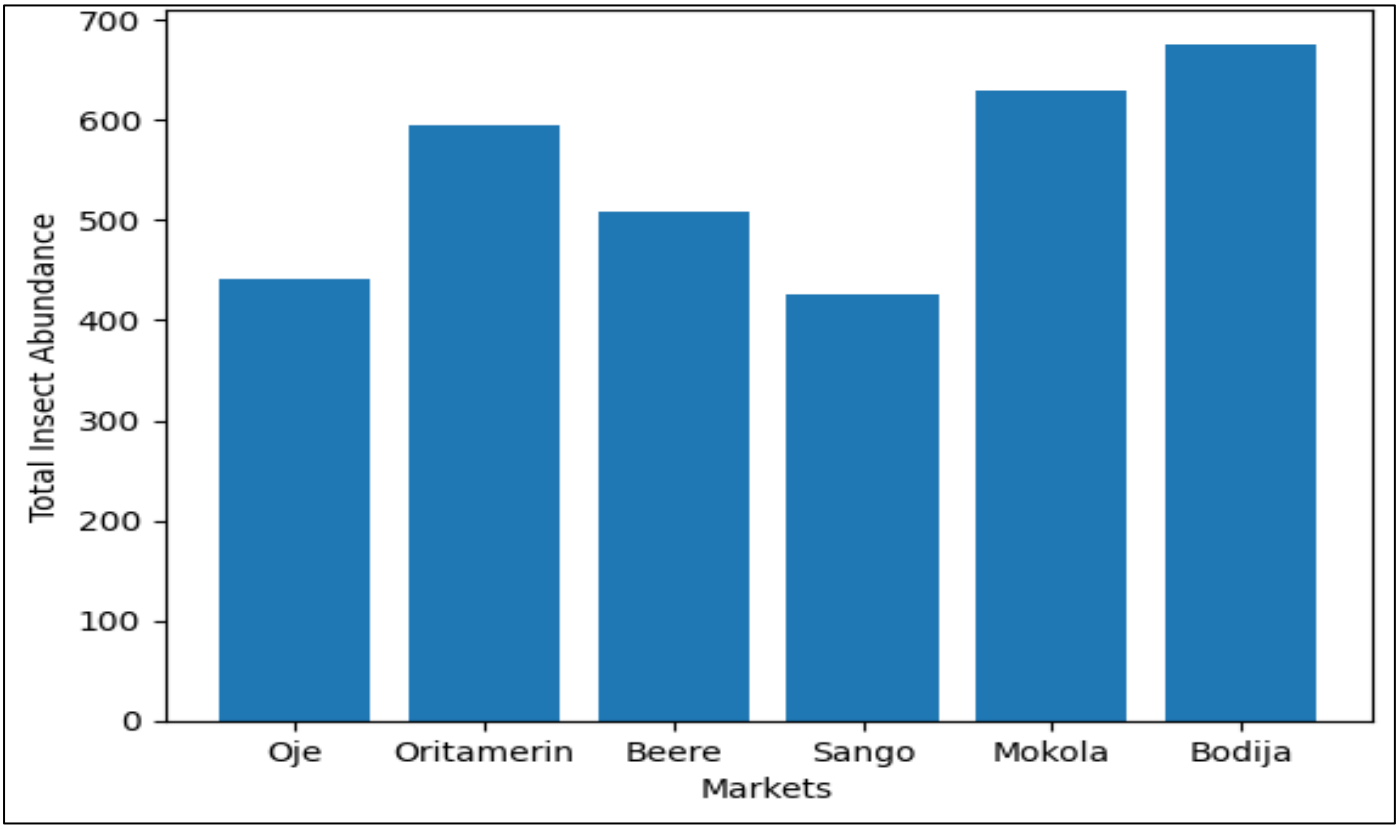

Fig 1 Distribution of Insect Abundance Across Six Vegetable Markets in Ibadan, Nigeria.

The identified insects belonged to four major taxonomic orders: Diptera (houseflies), Blattodea (cockroaches), Hymenoptera (ants), and Coleoptera (beetles). (Table 2, Fig 2)

Table 2 Relative Abundance and Percentage Occurrence of Insect Vectors

Common Name	Order	Total count	Percentage %
Houseflies	Diptera	901	27.52
Cockroaches	Blattodea	878	26.82
Ants	Hymenoptera	778	23.76
Beetles	Coleoptera	717	21.90
Total		**3274**	**100**

Overall, houseflies showed the highest abundance, accounting for 27.52% of the total insect population, followed by cockroaches (26.82%), ants (23.76%), and beetles (21.90%).

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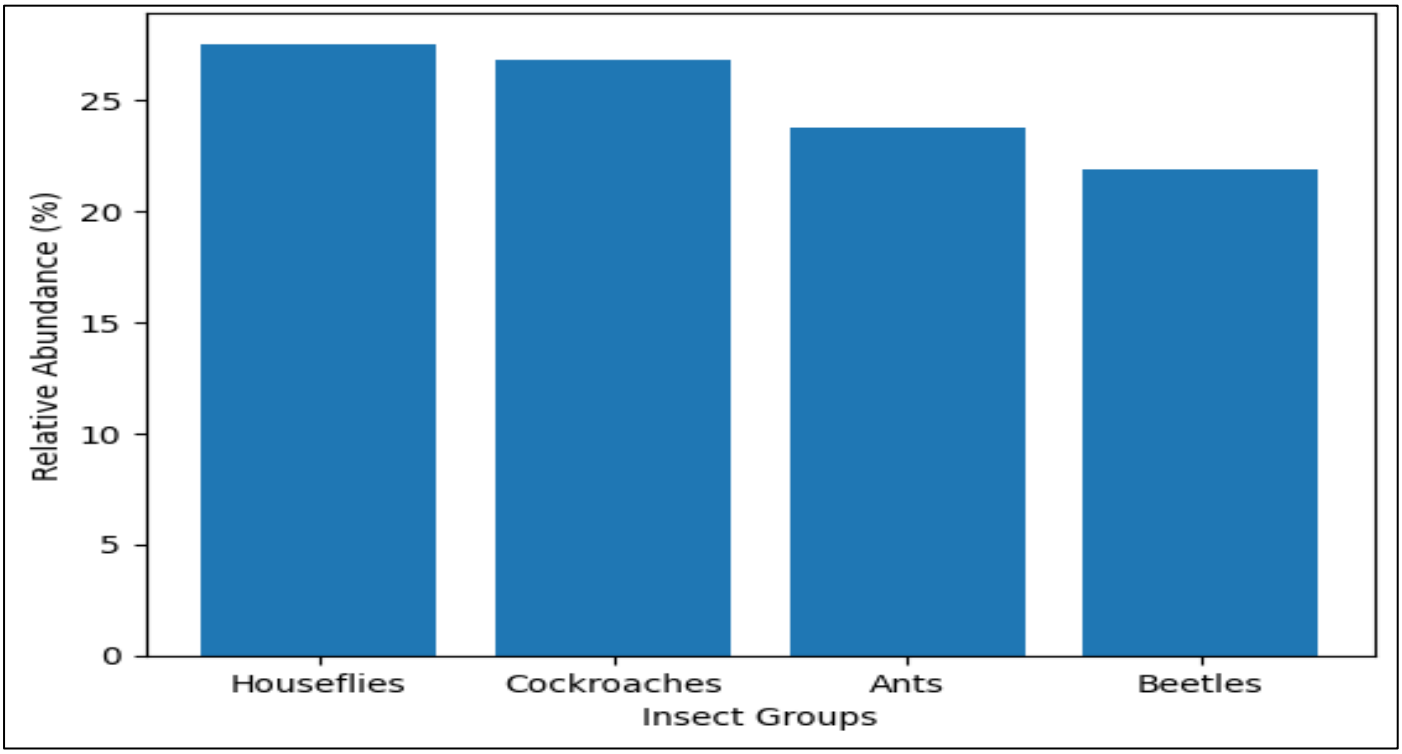

Fig 2 Relative Abundance (%) of Insect Groups Associated with Vegetable Retail Environments.

➢ *Market-Level Insect Diversity*

Ecological diversity indices were calculated to evaluate insect diversity across the sampled markets. The Shannon–Wiener diversity index (H′) ranged from 1.365 to 1.386, while the Simpson diversity index (1–D) ranged from 0.740 to 0.750.

The highest Shannon diversity value was recorded in Sango Market (H′ = 1.386), indicating slightly higher species evenness compared with other locations. Conversely, Bodija Market recorded the lowest Shannon index (H′ = 1.365), suggesting dominance by a few insect groups despite having the highest total abundance. Overall, the relatively similar diversity indices across markets indicate comparable insect community structures across vegetable retail environments in Ibadan, although abundance varied substantially between markets. (Table 3)

Table 3 Market-Level Insect Diversity

Markets	Total Individuals	Shannon-Wiener Index(H′)	Simpson Index(1-D)
Oje	441	1.384	0.749
Oritamerin	594	1.383	0.748
Beere	509	1.381	0.747
Sango	425	1.386	0.750
Mokola	629	1.385	0.750
Bodija	676	1.365	0.740

➢ *Statistical Comparison of Insect Distribution*

A Chi-square test of independence was performed to determine whether the distribution of insect groups differed significantly across the six markets in Ibadan. The analysis showed no statistically significant association between insect group and market location ($\chi^2 = 13.55$, df = 15, p = 0.56). This indicates that the relative distribution of the four insect groups was generally consistent across markets, although differences in overall abundance were observed.

Additionally, a one-way ANOVA comparing mean abundance among the insect groups showed no significant difference in their distribution across markets (F = 1.56, p = 0.23). These findings suggest that while some markets recorded higher insect numbers, the overall pattern of insect dominance remained similar across sampling sites.

IV. DISCUSSION

The present study revealed a high abundance and widespread distribution of insect vectors within vegetable retail environments in Ibadan, demonstrating the ecological suitability of open markets for synanthropic insects. Houseflies were the most abundant insect group across all markets, followed by cockroaches, ants, and beetles. This pattern is consistent with previous studies indicating that houseflies thrive in environments characterized by decomposing organic materials, waste accumulation, and frequent human activity. Yin, *et al* (2022)

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Houseflies are widely recognized as mechanical vectors of foodborne pathogens, capable of transporting microorganisms on their body surfaces, mouthparts, and digestive tract. Their feeding and breeding behavior exposes them to contaminated substrates such as waste dumps, manure, and decaying organic matter. Cockroaches (Order Blattodea) constituted the second most abundant insect group. Cockroaches are known to inhabit damp, waste-rich environments such as drains, refuse dumps, and food storage areas, enabling them to carry diverse microbial contaminants. Their ability to move between waste disposal sites and food preparation areas increases the risk of cross-contamination of fresh produce. Ghosh, A., et al. (2021). Ants (Order Hymenoptera) and beetles (Order Coleoptera) were also frequently encountered. Although these insects are less commonly emphasized as disease vectors compared with flies, they can still contribute to the mechanical transmission of microorganisms, particularly when they forage across contaminated surfaces. Kumar, P., et al. (2022)

These contaminated insects can subsequently transfer pathogens to food items, including fresh vegetables displayed in open markets. Studies have shown that synanthropic flies can transmit important foodborne pathogens including *Salmonella*, *Escherichia coli*, *Listeria monocytogenes*, and *Campylobacter* spp. through repeated contact with contaminated environments and food surfaces. Gonzalez *et al*, (2023)

Recent research has further highlighted the role of flies in the environmental dissemination of antimicrobial-resistant bacteria (ARB). For example, investigations have shown that houseflies can harbor multidrug-resistant E. coli, with resistance detected against commonly used antibiotics such as ampicillin and tetracycline. Such findings suggest that flies may act as important reservoirs and carriers of antimicrobial resistance genes (ARGs), potentially facilitating their spread across human, animal, and environmental interfaces. Singh, *et al*. (2025)

Experimental studies have also demonstrated that antimicrobial resistance plasmids can persist within the digestive tract of houseflies for several days after ingestion of contaminated bacteria, providing opportunities for bacterial survival and transmission. Similarly, investigations have reported the presence of antimicrobial-resistant Enterobacteriaceae and Salmonella in flies collected from agricultural environments, further highlighting the potential public health risk associated with these insects. Kimura *et al*. (2024), Gonzalez *et al*. (2023)

The high abundance of insects recorded in markets such as Bodija and Mokola may be linked to inadequate waste management, accumulation of organic debris, and high market traffic. These conditions provide favorable breeding habitats for insects, increasing the likelihood of contamination events. Urban markets in many developing countries often lack structured waste disposal systems, allowing decomposing organic materials to accumulate and serve as attractants for synanthropic insects. Abdullah, *et al*. (2024).

The findings of this study also support the One Health framework, which recognizes the interconnectedness of human health, environmental health, and animal health. Antimicrobial resistance is increasingly viewed as an ecological problem involving the circulation of resistant bacteria among humans, animals, food systems, and the environment. Insects such as houseflies and cockroaches may serve as ecological bridges that facilitate microbial exchange between these compartments. Akhtar, *et al*. (2023).

In addition to flies, cockroaches are also recognized carriers of pathogenic and antimicrobial-resistant bacteria. Their nocturnal habits and preference for damp environments such as drains and refuse piles allow them to acquire pathogens which may later be transferred to food handling surfaces. Reviews have highlighted that insects and other synanthropic animals can act as reservoirs and sentinels of antimicrobial resistance within urban ecosystems. Alemu, *et al*. (2022),

The presence of these insects in vegetable markets therefore represents a potential pathway for the contamination of fresh produce with pathogenic and antibiotic-resistant microorganisms. Fresh vegetables are commonly consumed raw or minimally processed, increasing the risk of foodborne disease transmission if contamination occurs. Anderson & Hurst (2021). Brennan, M., et al. (2023).. Osei-Sekyere, J., et al. (2024). Sharma, D., et al. (2023).

Although statistical analysis indicated no significant differences in insect group distribution across markets, the consistently high abundance recorded in all locations indicates that vector-mediated contamination risks are widespread in the study area. Improved environmental sanitation, waste management practices, and integrated pest management strategies are therefore essential to reduce insect populations and minimize contamination risks.

- *Challenges in Addressing Insect-Mediated Food Contamination*

Addressing insect-mediated contamination in open market environments presents several practical challenges. Informal market structures often lack proper sanitation facilities, waste management systems, and regulated food safety oversight. Vendors may have limited financial capacity to implement protective display methods or sanitation improvements.

Cultural practices and long-standing market norms also influence food handling behaviours, making behaviour change interventions difficult without sustained education and community engagement. Furthermore, insect control measures are often poorly coordinated or absent, allowing insect populations to thrive in waste-rich environments.

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Another major challenge is the limited integration of environmental health, food safety, and public health policies. Fragmented responsibilities among municipal authorities often result in ineffective implementation of sanitation and vector control programs. These systemic challenges highlight the need for coordinated, multisectoral approaches aligned with One Health principles.

➢ *Implications for Public Health Policy and Practice*

The findings of this study underscore the importance of incorporating insect control and environmental sanitation into food safety frameworks. Public health authorities should prioritize market hygiene improvement, waste management reforms, and vendor education programs as essential components of foodborne disease prevention strategies.

Routine monitoring of vegetables for microbial contamination and antibiotic resistance should be strengthened to identify emerging risks early. Public awareness campaigns focusing on proper vegetable washing, safe food handling, and environmental cleanliness could significantly reduce consumer exposure.

Importantly, policies should be guided by a One Health approach that recognizes the interconnected roles of environment, vectors, food systems, and human health. Integrated interventions involving health authorities, environmental agencies, market associations, and local governments are necessary to effectively mitigate insect-mediated contamination and the spread of antimicrobial resistance.

V. CONCLUSION

This study demonstrated that insect vectors are abundant and widely distributed in vegetable retail markets in Ibadan, with houseflies, cockroaches, ants, and beetles frequently encountered across sampling sites. The predominance of houseflies and cockroaches in particular highlights their potential role as mechanical vectors of microbial contaminants in fresh produce environments.

The presence of these insects in vegetable markets raises important public health concerns because synanthropic insects have been shown to harbor and disseminate pathogenic and antimicrobial-resistant microorganisms. Through their interactions with waste materials, contaminated surfaces, and food products, these insects may contribute to the environmental spread of antimicrobial resistance within urban food systems.

From a One Health perspective, addressing insect-mediated contamination requires integrated strategies that involve environmental sanitation, improved waste management, food safety monitoring, and pest control interventions. Strengthening hygiene practices within open food markets will be essential for reducing the risk of insect-borne contamination and safeguarding public health.

Overall, the findings underscore the need for coordinated public health and environmental management interventions aimed at minimizing insect proliferation and reducing the potential transmission of antimicrobial-resistant pathogens through fresh produce supply chains.

RECOMMENDATIONS

➢ *From the Findings of this Study, the Following Recommendations are Made:*

- Improvement of Market Sanitation: Regular waste removal, improved drainage systems, and proper refuse management should be implemented to reduce insect breeding sites within market environments.
- Vector Control Measures: Integrated insect control strategies, including environmental cleaning, physical barriers, and safe insect management practices, should be adopted in vegetable markets to limit insect access to exposed produce.
- Protective Display of Vegetables: Vendors should be encouraged to cover vegetables during display using clean nets, transparent containers, or other protective materials to minimize insect contact and environmental contamination.
- Public Health Education: Awareness programs should be conducted for vendors and consumers on hygienic handling of vegetables, risks associated with insect contamination, and the importance of washing produce before consumption.
- Strengthened Food Safety Surveillance: Routine microbiological monitoring of vegetables sold in open markets should be established to detect contamination and antibiotic resistance trends early.

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