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Bacteriological Assessment of Selected Fruits and Vegetables Sold in Major Open Markets in Lafia Metropolis, North-Central Nigeria

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Abstract
Fruits and vegetables serve as important sources of essential vitamins, minerals, and bioactive compounds, supporting total well-being and becoming a staple in many diets. The study examined bacterial contamination of selected fruits and vegetables sold in the major cities of Lafia in northern Nigeria. A total of 60 samples, 30 from each market, were collected from Alamis and Modern markets. This included cabbage, carrot, cucumber, onion, tomatoes, lettuce, pepper, watermelon, bitterleaf, and waterleaf. The samples were subjected to microbial analysis to determine the total heterotrophic bacterial count (THBC) and total coliform count (TCC) using the pour plate method. Nutrient and MacConkey agar were used for bacterial isolation. Statistical analysis was performed using chi-square (χ^2) tests in IBM SPSS version 28.0, with significance set at $p < 0.05$. The THBC and TCC recorded for samples from Alamis market ranged between 1.94×10^3 cfu/g and 4.00×10^3 cfu/g and 1.80×10^3 cfu/g and 5.64×10^3 cfu/g, respectively. Meanwhile, in the modern market, THBC varied from 1.42×10^3 cfu/g to 4.31×10^3 cfu/g, while TCC ranged from 1.04×10^3 cfu/g to 2.56×10^3 cfu/g. No significant relationship was observed between THBC and TCC across the samples. Identified bacterial species included *Salmonella* spp., *Shigella* spp., *Bacillus* spp., *Enterococcus faecalis*, *Escherichia coli*, *Proteus* spp., and *Staphylococcus aureus*. These findings highlight microbial contamination of fruits and vegetables and the need for public health measures to control the spread of infectious diseases caused by local foods in the region.

Keywords: Bacteria, Contamination, Fruits, Health effects, Vegetables

Introduction
Foodborne illnesses are a critical public health concern around the world, contributing to disease burden and mortality. It has been reported that approximately one in 10 persons suffers from foodborne infections because of contaminated food consumption, which leads to an estimated 420,000 deaths annually and 33 million years of health loss per year (World Health Organization, 2024; Almaary, 2023). Fruits and vegetables play a significant role in maintaining a healthy diet and supplying essential vitamins, minerals, and bioactive compounds that support overall well-being (Okunlola et al., 2023; Knez et al., 2024). In Nigeria and many other regions, increased awareness of their nutritional benefits has contributed to increased consumption (Mohammed & Qoronfleh, 2020). However, these foods are often consumed raw or with minimal processing and can serve as potential carriers for harmful microorganisms responsible for foodborne infections (Chen et al., 2022). There are different sources in which fruits and vegetables become contaminated, including soil, manure, fecal matter, irrigation water, dust, inappropriate handling during and after harvest, and inadequate storage or transport conditions (Adane & Tsehayneh, 2017; Mengistu et al., 2022). Additionally, certain market practices, such as sprinkling water to maintain produce freshness, may inadvertently introduce pathogenic microorganisms. Research has shown that fresh produce can harbor both beneficial microflora and harmful bacteria, including *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, and *Bacillus* species (Chaurasiya et al., 2021). Further research has identified foodborne pathogens such as *Vibrio* spp., *Campylobacter* spp., *Clostridium* spp., *Salmonella* spp., and *Shigella* spp. in fruits, vegetables, and ready-to-eat foods (Losio et al., 2015; Razzaq et al., 2014). Fruits and vegetables are valued for their low-calorie content and abundance of vitamins such as A, K, and B6, as well as minerals and dietary fiber (Asaolu et al., 2012; Sarker et al., 2020; Sivakumar et al., 2018), although, improper handling can pose a significant health risks as many consumers lack awareness of these dangers and often consume produce raw or inadequately washed fruits and vegetables thereby, increasing their susceptibility to foodborne infections (Samuel et al., 2019; Tamirat et al., 2014). Given the nutritional importance of fruits and

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vegetables and their potential to transmit foodborne pathogens, this study aims to assess the bacteriological quality of produce sold in Lafia Metropolis, North-Central Nigeria. By identifying microbial contaminants, the study seeks to inform consumers on the associated health risks in consuming contaminated fruits and within the populace.

Materials and Methods

Study area: This research was conducted in two major markets within Lafia Metropolis: Lafia Modern Market and Alamis Market. Lafia, the capital of Nasarawa State in North-Central Nigeria, has a diverse population with three major ethnic groups and several languages. According to the National Population Commission (NPC), the city's population is 430,474 (Ojo et al., 2023). As the state's largest urban center, Lafia is geographically located at 8.48° North latitude and 8.52° East longitude, with an elevation of 290 meters above sea level. This area experiences an average temperature of 31° C and a relative humidity of 64%.

Sample collection**:** A total of 60 fresh fruit and vegetable samples—30 from Alamis Market and 30 from Modern Market—were collected under aseptic conditions using clean, sterile polythene bags. The selected produce includes cabbage (*Brassica oleracea*), carrot (*Daucus carota*), cucumber (*Cucumis sativus*), onion (*Allium cepa*), tomatoes (*Lycopersicon esculentum*), lettuce (*Lactuca sativa*), pepper (*Capsicum spp*.), watermelon (*Citrullus lanatus*), bitterleaf (*Vernonia amygdalina*), and waterleaf (*Talinum triangulare*). Each sample was properly labeled and transported to the Microbiology Laboratory at the Federal University of Lafia, where further processing was performed within 6 hours of purchase.

Sample analysis: For microbial analysis, 25 grams of each fruit and vegetable sample were weighed and transferred into 225 mL of 0.1% (w/v) sterile bacteriological peptone water. The mixture was homogenized using a blender for 2–3 minutes to obtain a uniform dilution of 10^{-0} stock solution. A tenfold serial dilution was then performed for each sample up to a maximum dilution of 10^{-5}.

Total heterotrophic bacterial count (THBC): The pour plate method was employed to determine the total heterotrophic bacterial count. 0.1 mL aliquot of the 10^{-5} dilution was aseptically transferred to a sterile Petri dish, followed by the addition of 20 mL of sterilized molten nutrient agar (45°C). The plates were gently swirled for uniform distribution, then it was allowed to solidify, and incubated at 37°C for 24 hours. The resulting bacterial colonies were counted using a Gallenkamp colony counter, and the total bacterial count was expressed in colony-forming units per gram (CFU/g). Distinct colonies were sub-cultured for further identification.

Determination of total coliform count (TCC): The total coliform count was determined using the pour plate method. 0.1 mL portion of the 10^{-5} dilution was transferred into labeled sterile Petri dishes, and 20 mL of molten MacConkey agar (45°C) was added. The plates were swirled to ensure even distribution and incubated at 35–37°C for 24–48 hours. After incubation, the colonies were counted using a Gallenkamp colony counter, and the bacterial load was calculated as: $\text{CFU/g} = \frac{\text{No. of colonies} \times \text{Dilution factor}}{\text{Volume of diluent}}$

Isolation and characterization of bacterial isolates: Pure bacterial isolates were subjected to morphological and biochemical characterization to identify the species present, following standard laboratory procedures outlined by Cheesbrough (2006).

Data analysis and presentation: The data was analyzed in Statistical Package for the Social Sciences (SPSS) version 28.0 and Microsoft Excel. Appropriate statistical methods were applied to all quantitative data (McHugh, 2013). The chi-square test (χ^2) was employed to assess the relationships between variables at a 95% confidence level, and statistical significance was determined at $p < 0.05$ (Chan, 2003).

Results

Table 1: Total Heterotrophic Bacteria and Total Coliform Counts in Fruits and Vegetables Isolated from Alamis Market

Common names	Botanical names	THBC x 10^3CFU/g	TCC x 10^3 CFU/g
Cabbage	*Brassica oleracea*	4.00	2.42
Carrot	*Daucus carota*	3.22	5.64
Cucumber	*Cucumis sativus*	2.48	2.20
Onion	*Allium cepa*	1.94	1.14
Tomatoes	*Lycopersicon esculentum*	3.92	1.89
Lettuce	*Lactus sativus*	3.04	3.00
Pepper	*Solanideae capsicum*	2.16	1.80
Watermelon	*Citrullus lanatus*	2.00	1.92
Bitterleaf	*Vernonia amygdalina*	2.91	4.34
Waterleaf	*Hydrophyllum triangulare*	3.42	2.16
P-value		p = 0.98	p = 0.53

Significance level was set at $p < 0.05$. **THBC** – Total Heterotrophic Bacterial Count,
TCC – Total Coliform Count.

Table 2: Total Heterotrophic Bacterial Counts and Total Coliform Counts of Fruits and Vegetables Isolated from Modern Market.

Common names	Botanical names	THBC x 10^3CFU/g	TCC x 10^3 CFU/g
Cabbage	*Brassica oleracea*	2.93	1.04
Carrot	*Daucus carota*	2.20	2.15
Cucumber	*Cucumis sativus*	1.42	1.29
Onion	*Allium cepa*	2.82	1.68
Tomatoes	*Lycopersicon esculentum*	1.74	2.32
Lettuce	*Lactus sativus*	2.16	1.83
Pepper	*Solanideae capsicum*	1.88	2.56
Watermelon	*Citrullus lanatus*	4.31	1.42
Bitterleaf	*Vernonia amygdalina*	2.00	1.84
Waterleaf	*Hydrophyllum triangulare*	1.90	2.50
P-value		p = 0.89	p = 0.99

The significance level was set at $p < 0.05$. THBC – Total Heterotrophic Bacterial Count,
TCC – Total Coliform Count.

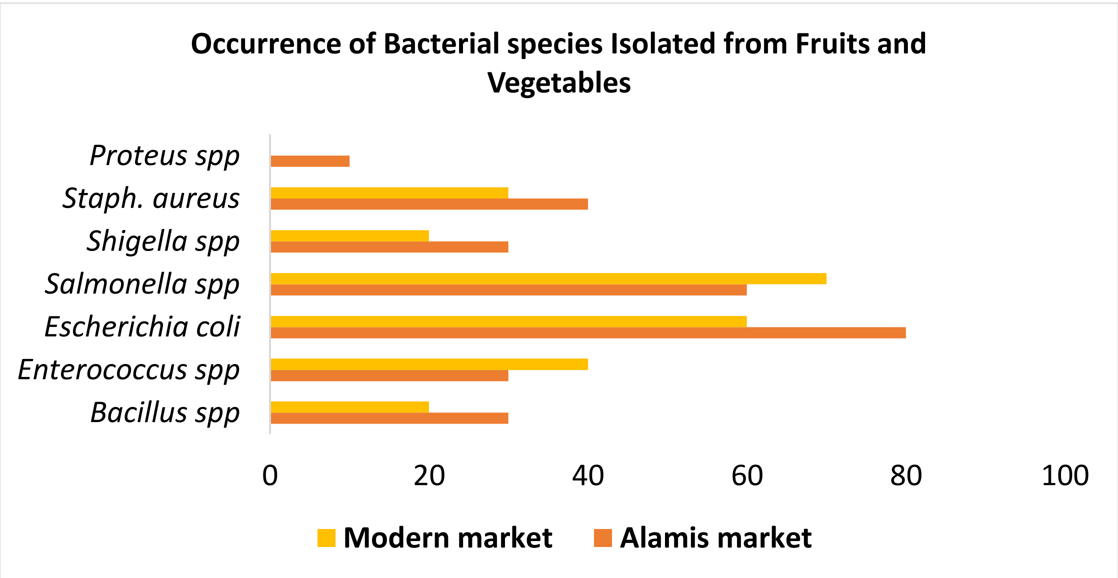

Figure 1: Bar chart showing the pathogens isolated from fruits and vegetables sold in Alamis and modern markets.

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Discussion

Tables 1 and 2 show the total heterotrophic bacterial count (THBC) and total coliform count (TCC) of fruits and vegetables in the Alamis and Modern markets. The recorded THBC and TCC values in Alamis market ranged from 1.94×10^3 CFU/g to 4.00×10^3 CFU/g and 1.80×10^3 CFU/g to 5.64×10^3 CFU/g, respectively. Meanwhile, the THBC and TCC in the modern market varied between 1.42×10^3 CFU/g and 4.31×10^3 CFU/g and 1.04×10^3 CFU/g and 2.56×10^3 CFU/g, respectively. These results suggest that the sampled tests from both markets contain microbial contamination. This exceeds the World Health Organization (WHO) and the International Commission on Microbiological Specifications for Foods (ICMSF), which determine the acceptable limits of 1×10^3 CFU/g for THBC and 100 CFU/g for TCC. Contamination is likely linked to insufficient washing, unhygienic handling, and exposure to contaminated water and surfaces. These observations align with findings by Sane et al. (2024), who reported microbial loads exceeding safety thresholds, with *E. coli* and *Vibrio* spp. reaching concentrations as high as 6.0×10^6 CFU/g and 8.73×10^6 CFU/g, respectively. Several studies examined the microbial contamination of ready-to-eat vended fruits, thereby emphasizing the associated health risks. Orji et al. (2016) reported total aerobic plate counts ranging from 3.5×10^5 CFU/ml to 1.03×10^6 CFU/ml in vended fruits in Nigeria. Their study identified seven bacterial species, including *Escherichia coli*, *Staphylococcus aureus*, *Shigella* spp., *Salmonella* spp., *Bacillus* spp., *Enterococcus faecalis*, and *Proteus* spp. (Figure 1). Among these, *E. coli* is the most frequently detected pathogen and raised concerns due to its association with diarrhea, urinary tract infections, pyogenic infections, and septicemia. The presence of *E. coli* indicates poor hygiene and poses a significant risk of foodborne infections. Potential contamination sources include the use of untreated wastewater for irrigation, the application of unprocessed fecal matter as fertilizer, and exposure to unsanitary water or surfaces during post-harvest processing (Ehuwa et al., 2021; Ford et al., 2018; Naranjo et al., 2019). Similarly, research by Igiehon et al. (2020) identified *E. coli*, *Shigella* spp., *Salmonella* spp., *Pseudomonas* spp., and *Staphylococcus aureus* in vended fruits, consistent with Li et al. (2021), who reported comparable bacterial contamination in fresh produce. *Salmonella* spp., a known causative agent of typhoid and paratyphoid fever, can contaminate fruits and vegetables through unsanitary water sources used for washing and processing, as vendors often do not have access to potable water. Sane et al. (2024) did not detect *Salmonella* spp.; Zhang et al. (2020) reported its presence in fresh-cut fruits and vegetables sold in Canadian retail markets.

Shigella spp., responsible for dysentery, can damage the intestinal mucosa, with some strains producing enterotoxins capable of causing hemolytic uremic syndrome (Samuel et al., 2019). The detection of coagulase-positive *Staphylococcus aureus* in fresh produce is primarily linked to handling by vendors, as the bacterium is commonly found on human skin and can be transferred through direct contact. Other identified bacteria, such as *Bacillus* spp., *Enterococcus faecalis*, and *Proteus* spp. This suggest fecal contamination (Balali et al., 2020), as these microorganisms are naturally present in the gastrointestinal tracts of humans and animals. Their presence in fruits and vegetables can be attributed to the use of untreated manure, contaminated irrigation water, or unhygienic post-harvest handling. These findings align with those reported by Igiehon et al. (2020) in a study that examines the safety of vended fruits in Thailand. Poor hygiene practices among vendors can further contribute to contamination. Handling fruits and vegetables after touching contaminated surfaces, such as door handles, ATMs, or currency notes, may introduce pathogens (Iyabo & Simon, 2019; Hassan et al., 2011). This issue is particularly a concern in developing regions where sanitation infrastructure, waste disposal, and hygiene regulations are often inadequate (Rashed et al., 2013). The presence of pathogenic microorganisms in vended fruits and vegetables is a significant risk to public health, especially since these foods are often consumed raw or minimally processed. Vulnerable groups, including children and the elderly, are exposed to an increased risk of foodborne illnesses. Thus, sensitization of appropriate hygiene providers and implementation of stricter safety regulations and monitoring measures is of great importance to mitigate these risks.

Conclusion

The increasing awareness of the health benefits associated with fruits and vegetables has contributed to a global increase in their production and consumption. However, this growing demand also creates challenges, especially when it comes to protecting consumers against food. The results of this study reveal a high microbial contamination in fruits and vegetables sold within the study area, indicating a significant risk of infection due to consumption. Notably, the level of contamination surpasses the threshold set by the International Commission on Microbiological Specifications for Foods (ICMSF) for indicator bacteria in fresh produce. An important observation in this study is the lack of effective control measures among traders to ensure the safety of fruits and vegetables. In large markets, these food items were often displayed on open surfaces and were exposed to contamination from environmental factors and human activities. Given these concerns, food regulators recommend that farmers, retailers, and consumers be more aware of potential health risks, as they are susceptible to infections, and therefore farmers, retailers, and consumers are still vulnerable to infections.

Recommendations

From the study on the bacteriological assessment of selected fruits and vegetables sold in major open markets in Lafia metropolis, north-central Nigeria, the following are recommended:

1. Vendors should be enlightened on proper handling and storage of fruits and vegetables to reduce contamination.
2. Consumers should be educated about the risks of consuming raw and unwashed fruits and vegetables.
3. Consumers should adopt proper washing with clean, potable water and mild disinfectants (such as salt solutions or vinegar) should be encouraged before consumption.
4. Regular monitoring and enforcement of hygiene standards in markets should be implemented.
5. More studies should be conducted to assess seasonal variations in microbial contamination of fruits and vegetables.

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