

Determination of Bacterial load of some selected fruits and vegetables sold in Kaduna Central Markets, Northwestern Nigeria.

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ABSTRACT

Fruits and vegetables served as the major sources of plant proteins, vitamins and fibers that support human health. This study was conducted to assess the bacteriological quality of some selected fruits and vegetables sold in Kaduna central market, northern Nigeria. A total of sixty (60) samples of fruits and vegetables were collected from Kaduna central market (Kaduna north local Government area), they include: Pepper (*Capsicum annum* L.), Tomato (*Lycopersicon esculentum* Mill.), Irish potato (*Solanum tuberosum* L.), Garden egg (*Solanum melongena* L.), Carrot (*Daucus carota* L.), Cucumber (*Cucumis sativus* L.), Water melon (*Citrullus lanatus* Thunb.), Onion (*Allium cepa* L.), Sweet potato (*Ipomoea batatas* L.) and Okra (*Abelmoschus esculentus* L.). The samples were analyzed using serial dilution technique and inoculation was done on MacConkey and Nutrient agar and incubated for 48 h. Results: The result obtained showed the presence of six bacterial species: *Staphylococcus aureus*, *Streptococcus sp.*, *Enterobacter sp.*, *Escherichia coli*, *Citrobacter sp.* and *Klebsiella sp.* *Staphylococcus aureus* was the most abundant (with 80% relative occurrence) while *Streptococcus sp.* was the least abundant with 2% relative occurrence. Conclusion: It was concluded that 6 different bacterial species prevailed on the fruits and vegetables sold in Kaduna central market: The result therefore implied that people consuming these fruits and vegetables are at a higher risk of pneumonia and toxic shock syndrome due to *Staphylococcal* infection, strep throat, rheumatic fever, scalded skin syndrome, scarlet fever and puerperal fever due to *S. aureus*, gastrointestinal disorders due to *E. coli* and bronchopneumonia due to *Klebsiella sp.* These findings highlight the 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. There is urgent need for orienting the general populace on the inherent dangers associated with consumption of these types of fruits and vegetables without thorough disinfection.

Keywords: Determination, Bacteria, load, fruits and vegetables

1.0 INTRODUCTION

Foodborne illnesses are of 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 are vital sources of nutrients to human beings. They give the body the necessary vitamins, fats, minerals and oil in the right proportion for growth and development. However, the existence of fruits and vegetables is threatened by various factors such as changes in climatic condition, pest, inadequate rainfall and the activities of different bacterial communities. 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 (Angbalagaet *al.*, 2025). In Nigeria and many other regions, increased awareness of their nutritional benefits has contributed to increased consumption (Angbalagaet *al.*, 2025). 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). Spoilage is defined by Tourna., 2005 as any change in the condition of food in which the food becomes less palatable or even toxic; these changes may be accompanied by alterations in taste, smell,

appearance or texture. The colonization process involves the ability of the bacteria to establish itself within the host. This is initiated when bacteria following adhesion and release of enzymes depolymerises certain specific cell wall polymers such as protopectin, the cementing substance of the produce. Susceptibility of fruits and vegetables is largely due to differential chemical compositions such as pH and moisture contents. The higher pH (near neutrality) and moisture content are associated with their greater predisposition to bacterial activities. The occurrence of bacterial species on fruits and vegetables is recognized as a source of potential health hazard to man and his animals. This is due to their production of bacteriotoxins compounds which are capable of inducing several critical clinical symptoms in man following ingestion or inhalation; even though they differ in their degree and manner of toxicity. Further research has identified foodborne pathogens such as *Vibriospp.*, *Campylobacter spp.*, *Clostridium spp.*, *Salmonella spp.*, and *Shigella spp.* in fruits, vegetables, and ready-to-eat foods (Losioet *al.*, 2015; Razzaq *et al.*, 2014). The microbes found in produce may have other, less direct, impacts on human health. Exposure to non-pathogenic microbes associated with plants may influence the development of allergies and the consumption of raw produce may represent an important means by which new lineages of commensal bacteria are introduced into the human gastrointestinal system Hanskiet *al.* 2012. The contamination of fruits and vegetables by bacteria could also be as a result of poor handling practices in food supply

chain, storage conditions, distribution, marketing practices and transportation (Efiuvwevwere, 2000). This study therefore, aimed at investigating the prevalence and occurrence of different bacterial communities on the fruits and vegetables sold in Kaduna central market with the view of identifying the different species of bacteria with their potential toxigenicity. The results of this research was also intended to be used in suggesting possible ways of minimizing or avoiding possible health problem associated with these bacterial species.

2.0 MATERIALS AND METHODS

2.1 Study Area

The research was conducted in Kaduna central market (Kaduna north local Government area), located along Ahmadu Bello Way, Kaduna state, Nigeria (lat 10E31'06.29"N and long 7E25'36.57"E).

2.2 Sample collection

A total of sixty (60) samples were collected from They include: Pepper (*Capsicum annum* L.), Tomato (*Lycopersicumesculentum* Mill.), Irish potato (*Solanum tuberosum* L.), Garden egg (*Solanum melongena* L.), Carrot (*Daucus carota* L.), Cucumber (*Cucumis sativus* L.), Water melon (*Citrullus lanatus*Thunb.), Onion (*Allium cepa* L.), Sweet potato (*Ipomoea batatas* L.) and Okra (*Abelmoschusesculentus* L.). The samples were collected twice monthly between April, 2017 to August, 2017 from the whole seller and retailer, put into a clean polythene bag and labelled, respectively. The samples were kept in the refrigerator at 4 °C for later use.

2.3 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.

2.4 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 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.

2.5 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: CFU/g = No. of colonies × Dilution factor Volume of diluent

2.6 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)

2.7 Biochemical tests

Biochemical tests were conducted to identify the gram negative bacteria by their metabolic activities focusing on enzymes and fermentation, The biochemical tests carried out include; Indole test; Methyl red test, Voges–Proskauer test, Citrate utilization test, Motility test, Urease test, Sugar fermentation to differentiate species especially members of the enterobacteriaceae family, using MacConkey agar and Eosin Methylene Blue Agar.

2.8 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).

3.0 RESULTS AND DISCUSSION

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

Common name	Botanical name	THBC ($\times 10^3$ CFU/g)	TCC ($\times 10^3$ CFU/g)
Pepper	<i>Capsicum annum</i> L.	4.00	2.42
Tomato	<i>Lycopersicumesculentum</i> Mill.	3.22	5.64
Irish potato	<i>Solanum tuberosum</i> L.	2.48	2.20
Garden egg	<i>Solanum melongena</i> L.	1.94	1.14
Carrot	<i>Daucus carota</i> L.	3.92	1.89
Cucumber	<i>Cucumis sativus</i> L.	3.04	3.00
Watermelon	<i>Citrullus lanatus</i> Thunb.	2.16	1.80
Onion	<i>Allium cepa</i> L.	2.00	1.92
Sweet potato	<i>Ipomoea batatas</i> L.	2.91	4.34
Okra	<i>Abelmoschus esculentus</i> L.	4.42	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: Biochemical characterization of Gram-positive bacterial isolated from vegetables and fruits

Vegetable /fruits	Hem	Coa	O	F	Bil	Cat	DNA	Inference
Tomatoes	α	+	+	-	-	+	+	<i>S. aureus</i>
Potatoes	α	+	+	-	-	+	+	<i>S. aureus</i>
Onion	-	-	-	-	-	+	+	<i>Staph. sp.</i>
Carrot	α	+	+	-	-	+	+	<i>S. aureus</i>
Garden egg	α	+	+	-	+	+	+	<i>S. aureus</i>
Sweet potato	α	+	+	-	+	+	+	<i>S. aureus</i>
Okra	β	-	+	-	-	-	+	<i>Streptococcus sp.</i>
Pepper	α	+	+	-	-	+	+	<i>S. aureus</i>
Watermelon	α	+	+	-	+	+	+	<i>S. aureus</i>

Key:

Hem = Haemolysis reaction;

Coa = Coagulase reaction;

O = Oxidase test;

F = Fermentation test;

Bil = Bile solubility;

Cat = Catalase test

Table 3: Biochemical characterization of Gram-negative bacteria isolated from vegetables and fruits

Vegetable /fruits	Ind	MR	VP	CIT	MOT	Urea	S/F	Inference
Tomatoes	+	+	-	-	+	-	K/AG	<i>E. coli</i>
Cucumber	-	-	-	+	+	--	K/A	<i>Klebsiella spp.</i>
Potatoes	+	+	-	-	+	-	K/AG	<i>E. coli</i>
Onion	-	-	-	+	+	-	K/A	<i>Klebsiella spp.</i>
Carrot	-	-	+	+	+	-	K/A	<i>Enterobacter sp.</i>
Garden egg	-	-	-	+	+	-	K/A	<i>Klebsiella spp.</i>
Sweet potato	+	+	-	-	+	-	K/AG	<i>E. coli</i>
Okra	-	+	-	+	+	+	K/AGH ₂ S	<i>Citrobacter spp.</i>
Pepper	-	+	-	+	+	+	K/AGH ₂ S	<i>Citrobacter spp.</i>
Watermelon	-	+	-	+	+	+	K/AGH ₂ S	<i>Citrobacter spp.</i>

Key:-

Ind = Indole test;

MR = Methyl red test;

VP = Voges-Proskauer test;

CIT = Citrate utilization test;

MOT = Motility test;

Urea = Urease test;

S/F = Sugar fermentation

Table 4: Percentage frequency of occurrence of bacterial isolates

Bacterial isolate	Frequency	Percentage (%)
<i>Escherichia coli</i>	2	4.00
<i>Staphylococcus aureus</i>	40	80.00
<i>Streptococcus spp.</i>	1	2.00
<i>Enterobacter spp.</i>	3	6.00
<i>Klebsiella spp.</i>	2	4.00
<i>Citrobacter spp.</i>	2	4.00
Total	50	100.00

Tables 1 indicated the total heterotrophic bacterial count (THBC) and total coliform count (TCC) of fruits and Vegetables sold in Kaduna central markets. The recorded THBC and TCC values 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. These results suggest that the samples contained 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. 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).

The presence of *E. coli* indicated 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) 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. The presence of *Staphylococcus* and *Streptococcus* species in the vegetables observed in this study agrees with the work of Erin., 2010 who reported the presence of *Staphylococcus* spp. in pawpaw, orange and kola nut at Sango Market, Ilorin. However, Wells *et al.*, 1997 reported *Salmonella*, *Shigella* and gastro-intestinal viruses as the major pathogens associated with food poisoning in England and the United States. 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 (Balaliet *al.*, 2020), as these microorganisms are naturally present in the gastrointestinal tracts of humans and animals, 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 Igiehonet *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).

Tables 2 and 3 indicated the results of biochemical characterization of Gram-negative bacteria on vegetables and fruits from Kaduna, from the results of biochemical analysis conducted all the organisms isolated were identified to genus level with the exception of *E. coli* and *Staphylococcus aureus* which were identified to specie level. The presence of other bacterial species of *E. coli*, *Enterobacter* spp., *Citrobacter* spp. and *Klebsiella* spp. in the vegetables obtained from Kaduna central market conforms to the findings of Rangel *et al.*, 2005 in which they reported the presence of *E. coli* in lettuce, apple, salads, coleslaw, melons, sprouts and grapes. The presence of *E. coli*, *Klebsiella*, *Citrobacter*, *Edwardsiella* and *Enterobacter* may lead to diarrheal diseases. It is also a well known enteric pathogen of man in nosocomial infections. This is in conformity with the findings of Pigott, 2008 that, the majority of human infections are caused by *Klebsiella pneumoniae* and *Klebsiella oxytoca*. The presence of *Citrobacter* spp. in the vegetables agrees with the findings of Uzehet *al.* 2009 who reported *Citrobacter* spp. in carrots, cucumber, cabbage and lettuce within Lagos Metropolis.

Table 4 showed the result of the Percentage frequency of occurrence of bacterial isolates. The bacteria found to spoil the vegetables were identified as *Klebsiella*, *Bacillus*, *E. coli*, *Staphylococcus*, *Pseudomonas* and there percentage frequency in vegetable sample was found to be 33.33%, 23.80%, 14.28%, 14.28% and 14.28%, respectively, the result obtained in the present study is in conformity with the work conducted by Adebayo *et al.*, 2012 on microorganisms associated with spoilage of stored vegetables including cabbage in Uyo metropolis, Akwa Ibom, Nigeria showed that *Escherichia coli* (28.6%) were the most predominant bacterial isolates associated with vegetable spoilage in Uyo metropolis. The finding of this study was also in conformity with that of Aminu and Aminu *et al.*, 2017 who investigated and assess the microorganisms associated with spoilage of Watermelon (*Citrullus lanatus*) and found that *Enterobacter* had 23% frequency of occurrence was the most predominant bacterial isolates associated with spoilage of water melon tested, followed by *Staphylococcus aureus* and *Salmonella* spp. (21%) each, *Escherichia coli* (19%).

4.0 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.

5.0 RECOMMENDATIONS

From the result obtained on bacterial load of selected fruits and vegetables sold in Kaduna Central Markets, Northwestern Nigeria, the following are recommended:

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

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