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ORIGINAL ARTICLE

Microbiological Quality of Common Snacks Found in Major Markets in Ondo City, Ondo State, Nigeria

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Abstract

Background: Ensuring high microbiological quality is essential for snacks because these foods are often consumed with minimal preparation, which leads to harmful pathogens during production. This study aims at determining the microbiological contamination of common snacks Found in major markets in Ondo City, Ondo State, Nigeria.
Methods: Fifty (50) samples of snacks namely, kulikuli, groundnut, cashew nuts, plantain chips, chinchin, coconut chips, wara and potato chips vended in five different markets within Ondo City, Ondo State Nigeria were obtained. The snacks were analyzed for total coliform count, specific pathogens using Pour plate method. Beta poisson model was used to estimate the risk of infection, illness, or death from exposure to pathogenic microorganisms. The data was statistically analysed by the use of IBM SPSS Statistics Data Editor version 25.
Results: The highest bacterial counts were observed in *Kulikuli*, particularly in samples from *Okedibo Market*, with values reaching up to 8.4×10^4 CFU/mL. *Okedibo Market* consistently shows high CFU counts across most snack types. *Cashew Nut* samples reached 5.3×10^4 CFU/mL, and *Coconut Chips* reached 5.7×10^4 CFU/mL. Other markets, like *Iyalaje Market* and *Sabo Market*, displayed lower and more consistent counts across most snacks. *Saluwa Market* had high bacterial counts for selected snacks (e.g., *Plantain Chips* at 3.1×10^4 CFU/mL). The probability of infection for each organism per meal per day remains quite low, ranging between 0.015 and 0.021, which is about 1.5% to 2.1%. Observations showed that *Escherichia coli* had a 100% chance of infection and has the highest yearly risk of infection when the snacks are consumed daily.
Conclusion: The yearly risk of illness (due to accumulation) was notably high for all the listed pathogens. The results highlight potential gaps in food safety protocols within certain markets which can be controlled by food safety regulations..

Keywords: Microbial quality, Snacks, *Escherichia coli, Shigella, Salmonella, Vibro cholera*

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Introduction

The microbiological quality of food, especially snacks, is crucial for ensuring consumer health and safety Mohamud, Khalifa, and Abuelhassan 2017 . The safety of snacks depends largely on the methods of preparations and the safety measures used. Snacks are commonlly consumed in between meals which are usually consumed in small quantities both by children and adults Ezekiel et al. 2015. There are different types of snacks found in different parts of the country which may be baked or fried. Examples of such snacks are 'kulikuli', popcorn, chinchin, etc. Acquisition of safe food has now become burning issue these days as folks are getting more aware of their health. The occurrence of food problems is increasing rapidly due to over population, changing lifestyles and emergence of new pathogens. Microbial contamination in food products is a pressing global issue that necessitates local investigations to address region-specific challenges Bevilacqua, Corbo, and Sinigaglia 2020. Unsafe food causes an estimated 600 million cases of foodborne illness and 420,000 deaths worldwide annually WHO 2020. Such illnesses can range from mild gastroenteritis to severe and life-threatening conditions, significantly impacting public health and economic productivity WHO 2020. Factors contributing to foodborne illnesses include population growth, urbanization, changing dietary habits, and emerging pathogens, including antibiotic-resistant strains Bevilacqua, Corbo, and Sinigaglia 2020. Hence, there is an urgent global call for improved food safety management practices, particularly in developing regions where these issues often receive inadequate attention Johnson et al. 2020.

Ready-to-eat snacks are highly susceptible to microbial contamination as they are commonly consumed without further cooking vended on the streets and open places, posing risks of foodborne diseases Smith and Brown 2019. Studies indicate frequent contamination of snacks sold in informal markets due to unhygienic conditions, improper handling, and inadequate sanitation Omorodion 2022. Pathogens commonly identified in snack foods include Escherichia coli, Salmonella spp., and Shigella spp., highlighting significant public health risks Muhammad et al. 2016. Therefore, understanding local microbial contamination patterns is critical for devising effective interventions aligned with global food safety objectives, particularly in regions like Ondo City, Nigeria.

Methods

Study Area

The study was carried out in *Ondo City*, Ondo State, Nigeria, with a focus on five major markets. Ondo City is the second largest city in Ondo State, located in the southwest of Nigeria in West Africa. The city has a population of about three hundred and fifty-eight thousand, four hundred and thirty people. Geographically, Ondo City is situated between 7°04′60.00″ N and 4°49′59.99″ E. The city is characterized by a humid tropical climate.

Samples were collected from five different markets in Ondo City: *Iyalaje Market*, *Okedibo Market*, *Sabo Market*, *Saluwa Market*, and *Adeyemi Market*.

Sample Collection

Snacks were randomly collected from five different major markets in Ondo City, Ondo State. Three different types of *kulikuli* and seven other types of snacks (*plantain chips, cashew nuts, groundnut, chin-chin, fried cheese, coconut chips, and potato chips*) were collected. Ten samples of each snack type were obtained, making a total of 50 samples. The selected markets — Okedibo, Iyalaje, Adeyemi, Sabo, and Saluwa — are well-patronized in Ondo City.

Collection, preservation, and transportation of samples to the laboratory were done with necessary precautions to ensure sample integrity at the point of laboratory analysis.

A bar chart generated using GraphPad Prism was used to determine the frequency of occurrence of various pathogenic organisms isolated from snacks purchased from different markets. This graphical representation facilitated a clear comparison of the prevalence of each organism across the markets.

Determination of Microorganisms in the Samples

Each sample was pounded using a mortar and pestle and placed in universal bottles. One gram (1g) of each sample was weighed into 9 ml of distilled water, and a serial dilution was performed for viable count using the pour plate method. One millilitre (1 ml) of the 10^{-3} dilution was introduced into a Petri dish.

5.4 g of Nutrient Agar was dissolved in 200 ml of distilled water and sterilized for 15 minutes. The sterilized agar was poured onto the diluted sample in the Petri dish. The plate was gently swirled to ensure proper mixing of the sample and the media, then allowed to solidify and incubated at 37°C for 24 hours.

The same process was repeated using different media: Thiosulphate Citrate Bile Salt (TCBS), Eosin Methylene Blue (EMB), MacConkey, and de Man Rogosa and Sharpe (MRS) at 37°C for 2–4 days in an incubation hood.

After the incubation periods, colony counts were performed and expressed as colony forming units per millilitre of sample (CFU/ml). Plates were divided into four quadrants; colonies were counted in one quadrant and multiplied by four. The number of colonies depended on their size .

Qualitative Microbial Risk Assessment Using Beta Poisson Model

The Beta Poisson model was used to estimate the risk of infection, illness, or death from exposure to pathogenic microorganisms in the snack samples. Point estimate Beta Poisson analysis was applied to assess the probability of these adverse health outcomes based on the concentration of pathogenic microorganisms present in the snacks.

Results

Plate Count of Bacteria from Snacks

The sample codes are presented in Table 1. The data in Table 2 provides bacterial viable plate counts from various snack types sampled across five different markets. The counts are expressed in *Colony Forming Units per milliliter (CFU/mL)*, which indicate the bacterial load on each snack type.

The highest bacterial counts were observed in *Kulikuli*, particularly in samples from *Okedibo Market*, with values reaching up to 8.4×10^4 CFU/mL.

Plantain Chips and *Coconut Chips* also show relatively high bacterial counts, especially in **Okedibo** and **Saluwa Markets**. Other snacks such as *Groundnut*, *Cashew Nut*, and *Chin-Chin* displayed moderate bacterial loads across different markets, with some variation but generally lower than *Kulikuli*. *Potato Chips* showed less variability in bacterial counts across all markets.

Snacks from **Okedibo Market** consistently showed high CFU counts. *Cashew Nut* samples and *Coconut Chips* samples recorded 5.3×10^4 CFU/mL and 5.7×10^4 CFU/mL, respectively, while snacks from **Iyalaje** and **Sabo Markets** displayed lower and more consistent counts. **Saluwa Market** has high bacterial counts for select snacks (e.g., *Plantain Chips* at 3.1×10^4 CFU/mL).

Snacks sampled from the same market but different batches (e.g., *Kulikuli* from **Iyalaje Market** samples A11, A12, and A13) exhibited variations in microbial content.

Qualitative Microbial Risk Assessment

Table 3 presents data on the probability of infections from consuming snacks contaminated with different pathogens. The table lists four pathogenic organisms that can contaminate snacks: *Vibrio cholerae*, *Escherichia coli*, *Salmonella* spp., and *Shigella* spp. It provides information on the average infective agents per 5 g of snacks, the amount of snacks ingested per day, the dose (presumably the amount of bacteria consumed), and the probability of infection per meal per day of consuming snacks.

Table 1. Beta-Poisson Model

Parameter	Dose-Response Model	Input Value	Reference
Probability of death/illness (P_i)	Beta-Poisson Model	0.001	Chowdhury et al., 2022
Shape parameter (k)	Beta-Poisson Model	0.0572	Amatobi and Agunwamba, 2022
Probability of illness/infection	Beta-Poisson Model	0.39	Dickinson et al., 2012
Beta-Poisson Equation	Beta-Poisson Formula	$P = 1 - (1 + D \cdot exp(1))^{-fi+}$	Dickinson et al., 2012

The probability of infection for each organism per meal per day was low, ranging between 0.015 and 0.021, which translates to about 1.5% to 2.1%. All listed pathogens show similar probabilities of causing infection despite varying average levels of bacteria and doses. *Escherichia coli* recorded the highest average presence in snacks (76 infective agents per 5 g), leading to the highest dose (0.38) and the highest infection probability (0.021 or 2.1%). *Vibrio cholerae*, although slightly lower in average infective agents (56 per 5 g), showed a similar infection probability (0.016 or 2%). *Salmonella* spp. and *Shigella* spp. recorded similar figures in terms of infective agents and probabilities, with a slightly lower infection risk than *Escherichia coli*.

Probability of yearly risk of microbes from snacks

Table 4 outlines the yearly risk of infection from consuming snacks contaminated with various microorganisms. It includes the following data for each organism: probability of infection per meal per day – this indicates the likelihood of contracting an infection from a single meal; number of ingestions per year – this assumes a yearly consumption of 365 meals; yearly risk of infection – this is expressed as a percentage, showing the annual risk based on daily exposure. Observations showed that Escherichia coli has the highest yearly risk, with a 100% chance of infection over a year if snacks containing this organism are consumed daily. This suggests that even a small per-meal probability (0.021) accumulates significantly over consistent exposure, leading to certainty in infection risk within a year. Vibrio cholerae shows a 99% yearly risk, only slightly lower than E. coli, indicating a high risk of cholera when consuming contaminated snacks daily. Salmonella spp has a yearly infection risk of 92%. This suggests a slightly lower but still high threat compared to E. coli and V. cholerae. Shigella spp presents an 88% yearly risk, making it the least risky of the four organisms listed, though still presenting a substantial health concern.

Probability of yearly illness and death

Table 5 provides insights into the yearly risk of illness and death from consuming snacks contaminated with specific microorganisms. Each entry in the Table presents yearly risk of illness (this is the annual probability of illness associated with each pathogen), yearly risk of death per meal and overall yearly risk of death (these indicate the per-meal and cumulative yearly probability of fatal outcomes due to each pathogen). The yearly risk of illness is notably high for all listed pathogens, ranging from 88% (Shigella spp) to 94% (Escherichia coli). Escherichia coli poses the highest risk of illness at 94%, closely followed by Salmonella spp (92%) and Vibrio cholerae (90%).

Discussion

Markets such as *Okedibo*, which displayed higher colony-forming units (CFUs) across multiple snacks, may lack adequate hygiene controls, increasing the risk of contamination. This consistently high bacterial load across multiple samples may indicate inadequate handling or processing standards specific to *Kulikuli* in some markets, potentially increasing the risk of microbial contamination and infection. Environmental factors in open markets, such as exposure to dust, insects, or contamination from other foods, may also compromise snack quality. Similar findings were reported by Omorodion 2022 where snacks sold in informal Nigerian markets exhibited high microbial contamination, with *E. coli* identified frequently, pointing toward poor vendor hygiene and environmental contamination. Potato Chips show less variability and relatively consistent bacterial counts across all markets, suggesting that preparation or preservation methods for potato chips may offer better protection against bacterial growth. Closed and controlled environments are preferable for limiting contamination during food handling and storage Awuchi 2023. High levels of bacteria in snacks are associated with an increased risk of foodborne illnesses, as highlighted in Tables 4 and 5. Although not all bacteria present are pathogenic, the presence of known pathogens like *E. coli* and *Salmonella spp.* points to a significant health risk, especially for vulnerable groups such as children, the elderly, and individuals with compromised immune systems Silaen 2024. The presence of these pathogens in the current study aligns closely with findings by Muhammad et al. 2016, who identified similar contamination profiles in street-vended snacks from Nigerian markets. They reported that the frequent detection of fecal indicator bacteria (e.g., *E. coli*) directly correlated with insufficient sanitation facilities and personal hygiene among vendors. Poor microbiological quality in snacks can lead to outbreaks of foodborne illness, incurring costs related to healthcare, reduced productivity, and potential legal liabilities for vendors Abuagla and Omer 2025. Consistently high microbial loads in snacks could undermine consumer confidence, impacting the market. Packaging snacks in sealed containers can prevent moisture exposure and microbial infiltration. Furthermore, low-moisture, oxygen-free packaging (e.g., vacuum-sealing) can help inhibit bacterial growth over time Serna-Saldivar 2022. Educating vendors on safe handling practices and the importance of hygiene, along with raising consumer awareness about checking packaging

Table 2. Viable plate count of bacteria from snacks (CFU/mL)

Snack Type	Market	Sample	Total Count	CFU/mL
Kulikuli	Iyalaje Market	A11	15	1.5×10^4
		A12	17	1.7×10^4
		A13	14	1.4×10^4
	Saluwa Market	A21	22	2.2×10^4
		A22	14	1.4×10^4
		A23	21	2.1×10^4
	Okedibo Market	B1	75	7.5×10^4
		B2	84	8.4×10^4
		B3	53	5.3×10^4
	Sabo Market	C1	50	5.0×10^4
		C2	33	3.3×10^4
		C3	27	2.7×10^4
	Adeyemi Market	D1	35	3.5×10^4
		D2	56	5.6×10^4
		D3	32	3.2×10^4
Groundnut	Okedibo Market	E1	17	1.7×10^4
	Iyalaje Market	E2	18	1.8×10^4
	Sabo Market	E3	27	2.7×10^4
	Saluwa Market	E4	38	3.8×10^4
	Adeyemi Market	E5	37	3.7×10^4
Cashew Nut	Okedibo Market	F1	52	5.2×10^4
	Iyalaje Market	F2	18	1.8×10^4
	Sabo Market	F3	36	3.6×10^4
	Saluwa Market	F4	73	7.3×10^4
	Adeyemi Market	F5	41	4.1×10^4
Plantain Chips	Okedibo Market	G1	57	5.7×10^4
	Iyalaje Market	G2	31	3.1×10^4
	Sabo Market	G3	35	3.5×10^4
	Saluwa Market	G4	31	3.1×10^4
	Adeyemi Market	G5	48	4.8×10^4
Chin-Chin	Okedibo Market	H1	38	3.8×10^4
	Iyalaje Market	H2	28	2.8×10^4
	Sabo Market	H3	20	2.0×10^4
	Saluwa Market	H4	40	4.0×10^4
	Adeyemi Market	H5	65	6.5×10^4
Coconut Chips	Okedibo Market	I1	37	3.7×10^4
	Iyalaje Market	I2	36	3.6×10^4
	Sabo Market	I3	54	5.4×10^4
	Saluwa Market	I4	67	6.7×10^4
	Adeyemi Market	I5	38	3.8×10^4
Wara (Fried Cheese)	Okedibo Market	J1	32	3.2×10^4
	Iyalaje Market	J2	44	4.4×10^4
	Sabo Market	J3	27	2.7×10^4
	Saluwa Market	J4	40	4.0×10^4
	Adeyemi Market	J5	35	3.5×10^4
Potato Chips	Okedibo Market	K1	44	4.4×10^4
	Iyalaje Market	K2	47	4.7×10^4
	Sabo Market	K3	46	4.6×10^4
	Saluwa Market	K4	43	4.3×10^4
	Adeyemi Market	K5	27	2.7×10^4

Table 3. Probability of infections from snacks per meal per day

Organism	Infective Agents per 5g	Snack Amount (g/day)	Dose	Probability of Infection/Day
Vibrio cholerae	56	0.005	0.28	0.016 (2%)
Escherichia coli	76	0.005	0.38	0.021 (2%)
Salmonella spp.	64	0.005	0.32	0.018 (2%)
Shigella spp.	53	0.005	0.27	0.015 (2%)

Table 4. Probability of yearly risk of microbes from snacks

Organism	Probability of Infection per Day	Days per Year (N)	Yearly Risk of Infection
Vibrio cholerae	0.016	365	0.99 (99%)
Escherichia coli	0.021	365	0.99 (100%)
Salmonella spp.	0.018	365	0.92 (92%)
Shigella spp.	0.015	365	0.88 (88%)

Table 5. Probability of yearly illness and death

Organism	Yearly Risk of Illness	Yearly Risk of Death per Meal	Total Yearly Risk of Death
Vibrio cholerae	0.90 (90%)	0.00 (0%)	0.00 (0%)
Escherichia coli	0.94 (94%)	0.00 (0%)	0.00 (0%)
Salmonella spp.	0.92 (92%)	0.00 (0%)	0.00 (0%)
Shigella spp.	0.88 (88%)	0.00 (0%)	0.00 (0%)

integrity, storage, and expiration dates, can reduce risks Okpala and Korzeniowska 2023. Advanced testing methods, such as DNA-based identification or rapid pathogen detection kits, enable more effective quality control. Technologies such as high-pressure processing (HPP) and irradiation can reduce bacterial counts in snacks without compromising quality, providing a safer alternative to traditional preservation methods (Haque et al., 2023). Implementing standard operating procedures (SOPs) for snack preparation and handling, with clear guidelines for hygiene, can help limit bacterial contamination Okeke et al. 2021. Educating vendors and consumers on foodborne illness risks associated with bacterial contamination could improve food safety practices and consumer awareness, especially in areas with high bacterial contamination in snacks Omorodion 2022. The result shown in (Table 3-5) shows the potential health risk associated with the microbial contamination in snacks based on the organisms isolated in this study . The analysis focused on four organisms (*vibrio cholerae, Escherichia coli, salmonella spp, and shigella spp*). These results resonate with findings from a risk assessment study by Bevilacqua, Corbo, and Sinigaglia 2020, who reported that consistent exposure to even minimal contamination could substantially elevate cumulative infection risks over time. Reducing daily exposure, improving food processing techniques, and implementing better storage methods could significantly lower the yearly infection risk Awuchi 2023. Awareness programs highlighting the risks associated with contaminated food could help reduce consistent exposure, lowering overall health risks.

The data strongly suggests that while single instances may seem low-risk, the cumulative impact of consistent daily consumption of contaminated food can lead to near certainty of infection, making it a public health priority to minimize exposure to these pathogens. The high probability of illness recorded in (Table 5) underscores the importance of addressing microbial contamination in snack foods. Such high infection rates could lead to widespread illness if contamination is not managed. The potential healthcare burden, economic losses, and decreased productivity from these infections should not be underestimated, as underscored by the WHO 2020. Although the absence of death risk might reduce the perceived urgency, the high illness rates warrant robust preventative measures to limit exposure. Strategies could include improved sanitation during snack production, better food safety regulations, and consumer education on proper food handling and storage Sameen et al. 2023. Given the high probability of illness, regulatory authorities should ensure food safety protocols specifically targeting these microorganisms in snack production Sameen et al. 2023. While the analyzed pathogens may not be fatal based on the current data, their high potential to cause illness suggests a significant public health risk. Efforts to curb contamination and raise public awareness are essential to reduce the substantial illness burden they impose.

Conclusion

The findings highlight potential gaps in food safety of snacks sold in some markets within Ondo city , with Okedibo market showing high bacterial counts across multiple snack types. This may point to underlying issues such as inadequate sanitation, improper storage, or handling practices that are not effectively controlling bacterial growth. Addressing these issues through better regulation and consistent food handling practices can reduce bacterial contamination, making snacks safer for consumption. The similarity in infection probabilities despite varying bacteria levels highlights the importance of minimizing contamination across all types of pathogens. The data strongly suggests that while single instances may seem low-risk, the cumulative impact of consistent daily consumption of contaminated food can lead to near certainty of infection, making it a public health priority to minimize exposure to these pathogens. While the analyzed pathogens may not be fatal based on the current data, their high potential to cause illness suggests a significant public health risk. Efforts to curb contamination and raise public awareness are essential to reduce the substantial illness burden they impose.

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