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Occurrence of Enteric Bacteria in Tiger nuts and their Products in Port Harcourt Metropolis, Nigeria

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ABSTRACT

Tiger nuts (*Cyperus esculentus* L.) and its products are commonly consumed in Nigeria and may be exposed to microbial contamination during harvesting, processing, handling, storage and vending. This study examined the occurrence of enteric bacteria in tiger nuts and their products in Port Harcourt, Nigeria. A total of 48 samples were examined using standard microbiological procedures. Samples involved 18 dried tiger nut samples soaked overnight in laboratory conditions, 18 fresh tiger nut samples from the markets, and 12 vended tiger nut drinks. Data from the study revealed that both the dried and fresh samples obtained from Oil Mill Market had the highest mean *Salmonella-Shigella* count (SSC) $13.96 \pm 11.19 \times 10^4$ CFU/g, and total coliform count (TCC) $11.86 \pm 11.68 \times 10^5$ CFU/g, while samples from Mile 1 Market had the lowest SSC. There were no statistically significant difference observed ($p>0.05$). Data obtained indicated that the fresh TIger nuts samples had higher count for both SSA ($10.97 \pm 9.83 \times 10^4$ CFU/g) and TCC ($11.03 \pm 9.90 \times 10^5$ CFU/g) while the dried Tiger Nuts samples recorded lower count for both SSA ($1.33 \pm 11.65 \times 10^4$ CFU/g) and TCC ($1.59 \pm 11.20 \times 10^5$ CFU/g) with no statististival difference ($P> 0.05$) . Among the tiger nut drinks samples, samples from Mile 1 Market had the highest mean SSC ($2.67 \pm 0.31 \times 10^5$ CFU/mL) and TCC ($2.76 \pm 0.05 \times 10^6$ CFU/mL), with samples from the eateries recording the lowest mean value. Differences among sampling points were statistically significant ($p < 0.05$). The results showed that *Citrobacter* spp. was predominant in the dried tiger nut samples, *Proteus* spp. in the fresh tiger nut samples, and *Shigella* spp. in the tiger nut drink samples. The findings have demonstrated that tiger nuts and their products sold within the study locations harbour various enteric bacteria of public health and food-safety significance. The occurrence of these organisms across the different sample categories highlights the potential for microbial contamination at various stages of production, processing, handling, storage and vending. These findings underscore the importance of implementing and maintaining proper hygienic practices, adequate sanitation and appropriate storage conditions to minimise bacterial contamination and improve the microbiological quality and safety of tiger nuts and their products consumed in Port Harcourt Metropolis.

Keywords: *Cyperus esculentus*, Tiger Nuts, Enteric Bacteria, Bacterial Load, Occurrence, Food Safety, Public Health.

Introduction

Tiger nut (*Cyperus esculentus L.*) is a perennial, grass-like plant that belongs to the *Cyperaceae* family (Sánchez-Zapata et al.2012). It is a tuber crop that remains underutilized yet has drawn growing interest owing to its nutritional, functional, and economic value (Yu et al. 2022). Tiger nuts, also referred to as earth almonds, chufa, and yellow nuts edge, are eaten in various parts of Africa, Europe, and other regions. In Nigeria, tiger nuts are eaten as they are or processed into drinks and other food products. The crop holds appreciable quantities of carbohydrates, dietary fibre, lipids, proteins, vitamins, minerals, and other bioactive Compounds which makes it a nutritionally valuable food resource (Adejuyitan, 2011; Yu et al., 2022).

Tiger nut tubers are typically small, fibrous, wrinkled, and somewhat sweet, with varieties that vary in size and colour. Their nutritional makeup consists of carbohydrates, dietary fibre, oils abundant in unsaturated fatty acids, proteins, vitamins, minerals, and phytochemicals (Adejuyitan, 2011).

These constituents contribute to the nutritional and functional properties of the crop. Studies have likewise documented antioxidant and other biological activities linked to tiger nut constituents.

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However, how pronounced these effects are depends on the variety, processing method, and conditions of consumption (Yu et al., 2022; Edo et al*.,* 2024).

Tiger nuts may be consumed in different forms, including raw, dried, roasted, ground into flour, processed for oil extraction, or used in the preparation of beverages. One of the most popular products is tiger nut milk, locally known in Nigeria as Kunun-aya. This beverage is produced by extracting the soluble components of soaked and milled tiger nuts using water. The extraction process involves soaking, wet milling, filtration and separation of the liquid extract from the fibrous residue.

The nutritional and physicochemical properties of the resulting beverage are influenced by processing conditions, including soaking duration, milling intensity, water-to-tuber ratio and extraction procedures (Costa Neto et al., 2017; Kizzie-Hayford et al., 2015). Kizzie-Hayford et al. (2015) reported that milling duration influenced the yield, nutrient transfer, colour and colloidal stability of tiger nut milk, with prolonged milling improving milk solids yield and certain nutritional characteristics. Similarly, Okorie et al. (2024) demonstrated that preprocessing methods, including soaking, boiling and malting, influenced the proximate composition of tiger nut milk.

In Nigeria, the beverage is frequently prepared with additional ingredients such as ginger, dates and coconut to improve its flavour and sensory characteristics. Eke-Ejiofor and Awaji (2019) investigated the microbiological and storage properties of spiced tiger nut drinks prepared with ginger and other locally available spices, while Akubuenyi and Sylvanus (2022) documented the preparation of Kunun-aya using tiger nuts and dates. Furthermore, Eruteya et al. (2024) investigated the nutritional and microbiological quality of vended tiger nut drinks in Choba, Rivers State, highlighting the relevance of hygienic processing and handling in ensuring the safety of the beverage.

Tiger nut milk is regarded as one of the plant-based milk alternatives. Plant-based beverages have gained increasing attention because they provide alternatives for individuals who avoid or cannot tolerate conventional cow's milk, including those with lactose intolerance and individuals who follow plant-based diets (Sethi et al., 2016; Mäkinen et al., 2016).

However, the nutritional composition, physicochemical properties and consumer acceptability of these beverages depend on the plant material, processing conditions, formulation and storage practices. Differences in processing and preservation techniques may also influence their nutritional quality, microbial stability and shelf life (Mäkinen et al., 2016).

Despite its nutritional value, tiger nut milk is susceptible to microbial contamination and spoilage because its high moisture content and available nutrients can support microbial growth. The microbiological quality of the beverage may be influenced by the quality of the raw tiger nuts, water used during processing, processing equipment, handling practices, environmental conditions and storage temperature. Ibrahim et al. (2017) investigated the influence of preservation methods on the pH and microbiological quality of tiger nut milk and reported changes in pH associated with microbial activity during storage.

Similarly, Babatuyi et al. (2019) investigated the microbiological and physicochemical characteristics of tiger nut milk during storage and reported changes in microbial populations and product quality. These findings suggest that processing conditions, hygiene and storage practices play important roles in determining the occurrence of microorganisms in tiger nut beverages.

The occurrence of enteric bacteria in tiger nut products is of particular public health importance because some members of this bacterial group are associated with foodborne infections. *Escherichia coli* is an important example, as certain pathogenic strains are associated with gastrointestinal infections and diarrhoeal diseases (Kaper et al., 2004). Similarly, *Salmonella* and *Shigella* species are recognised enteric pathogens associated with foodborne and waterborne diseases. Other enteric bacteria, including *Klebsiella*, *Proteus* and *Citrobacter* species, may also be recovered from contaminated foods and beverages, although their pathogenic significance varies among species and strains. The occurrence of these organisms in ready-to-consume products may indicate contamination during production, processing, handling or storage. However, the detection of an enteric bacterium does not necessarily establish its source of contamination or confirm that the isolate is pathogenic.

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Previous studies have documented the occurrence of microorganisms in tiger nut beverages sold in different parts of Nigeria. Ire et al. (2020) investigated the microbiological quality of ready-to-drink tiger nut beverages sold within Port Harcourt metropolis, Rivers State, and reported the occurrence of different bacterial organisms in the sampled beverages.

Similarly, Eruteya et al. (2024) assessed the nutritional and microbiological quality of vended tiger nut drinks in Choba, Rivers State, and documented bacterial contamination in the products examined.

These findings demonstrate that tiger nut beverages sold within Port Harcourt and its environs may harbour microorganisms of public health significance. Nevertheless, studies focusing on beverages alone may not adequately describe the occurrence of enteric bacteria across other forms of tiger nut products, particularly dry and soaked tiger nuts.

Port Harcourt is an important commercial centre in Rivers State, with numerous markets, eateries, schools, transport hubs and residential communities where locally processed foods and beverages are sold. Tiger nuts and their products are readily available in these settings and are consumed in raw, soaked and processed forms. However, exposure to contaminated water, unhygienic processing equipment, improper handling and unsuitable storage conditions may contribute to the occurrence of enteric bacteria in these products.

Although previous investigations have examined the microbiological quality of tiger nut beverages in Port Harcourt, further investigation is necessary to provide a broader understanding of the occurrence and distribution of enteric bacteria in dry tiger nuts, soaked tiger nuts and processed tiger nut products obtained from different vending locations.

Therefore, the present study focuses on the occurrence of enteric bacteria associated with tiger nuts and their products sold in Port Harcourt Metropolis.

The findings from this study will provide important data for public and food safety compliance monitoring with relevant to SDG 3 to protect public health by reducing the risks of food borne illness due to enteric bacteria and SDG 12 to ensure responsible production and consumption by ensuring a safe and sustainable food chain.

Materials and Methods

Study Area

The study area was Port Harcourt metropolis, in River State, located in Southern Nigeria. The selected areas were; Rumuokoro Market in Obio/Akpor Local Government Area, Oil mill Market in Obio/Akpor Local Government Area, and Mile 1 Market in Port Harcourt Local Government Area.

Study Design

A cross-sectional study design was adopted to investigate the occurrence of enteric bacteria associated with tiger nuts and their products sold in Port Harcourt metropolis, Rivers State, Nigeria. Sampling was carried out between January and June 2025. The study involved the collection and microbiological examination of tiger nut samples, including dried tiger nuts, soaked tiger nuts and processed tiger nut products, obtained from selected markets and eateries across the study locations.

Sample collection

A total of 48 samples of tiger nut products were collected from vendors across the three selected locations. The samples comprised 18 dried tiger nut samples, 18 fresh tiger nut samples, and 12 tiger nut drink samples. The dried and fresh tiger nut samples were collected in sterile, sealed zip-lock bags, while the packaged tiger nut drinks were placed in cooler containing ice packs to maintain a temperature of approximately 4°C during transportation. All samples were promptly transported to the laboratory for analysis. The dried and fresh Tiger nuts were sampled twice but the Tiger nut drinks were sampled once.

Laboratory preparation of dried Tiger nut

The dried tiger nut samples were carefully sorted to remove foreign materials, debris, and visibly damaged or deteriorated nuts. The selected tiger nuts were thoroughly washed with sterile distilled water to remove adhering soil, dirt and other surface contaminants. After washing, the samples were transferred into a 250 mL conical flask containing sterile distilled water. The mouth of each flask was covered with sterile cotton wool to minimise exposure to airborne contaminants during soaking. The samples were then soaked for 24 hours under laboratory conditions to facilitate rehydration; following a similar soaking procedure described by Banwo and Taiwo (2025).

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The use of appropriate sample preparation and handling procedures was guided by ISO 6887-1:2017. Following the soaking period, the rehydrated tiger nuts were drained and subsequently crushed aseptically before microbiological analysis.

Enumeration and isolation of enteric bacterial in the samples

The dried and fresh tiger nut samples were crushed separately under aseptic conditions. Thereafter, ten grams (10 g) of each crushed sample were aseptically transferred into 90 mL of sterile normal saline to obtain an initial 10^{-1} suspension. The mixtures were thoroughly homogenised to ensure uniform distribution of microorganisms within the suspensions. Subsequently, ten-fold serial dilutions were prepared by aseptically transferring 1 mL of each suspension into 9 mL of sterile normal saline, with the dilution process repeated sequentially to obtain dilutions up to 10^{-4}.

For the tiger nut drink samples, 1 mL of each sample was aseptically transferred into 9 mL of sterile normal saline and thoroughly mixed to obtain the initial 10^{-1} dilution. Further ten-fold serial dilutions were prepared by transferring 1 mL from each preceding dilution into 9 mL of sterile normal saline until a final dilution of 10^{-4} was obtained.

Using the spread plate technique, 0.1 mL aliquots from the dilutions of each tiger nuts sample were aseptically inoculated in duplicate onto separately prepared plates of Eosin Methylene Blue (EMB) Agar, *Salmonella–Shigella* Agar (SSA) and MacConkey Agar. The inoculated samples were evenly distributed over the agar surfaces using a sterile spreader to facilitate the development of discrete bacterial colonies. The plates were subsequently incubated at 37°C for 24–48 hours, according to the incubation requirements of the respective culture media. Following incubation, the colonies were examined for their cultural and morphological characteristics, while discrete colonies were counted and recorded for bacterial enumeration. Representative colonies were subsequently selected for further isolation and identification of enteric bacteria.

Characterization of the bacterial species

The bacterial isolates were phenotypically characterized based on their cultural characteristics on *Salmonella–Shigella* Agar (SSA), Eosin Methylene Blue (EMB) agar, and MacConkey agar. On SSA, presumptive *Shigella* isolates appeared as light-pink colonies, while presumptive Salmonella isolates appeared as black colonies. On EMB agar, presumptive *Escherichia coli* isolates exhibited green colonies. On MacConkey agar, both pink and colourless colonies were observed, indicating differences in the lactose-fermenting characteristics of the bacterial isolates. These observed cultural characteristics were recorded and used for the preliminary differentiation of the bacterial isolates.

Selected colonies on the enumerated plates were subcultured into nutrient agar plate to obtain pure culture for characterization and identifications. The plates were incubated at 37^0 for 24 hours.

Morphological characteristics of the isolates

The isolates were subjected to Morphological characterization through Gram staining and microscopic examination. Heat fixed smears of the isolates were prepared on labelled clean microscope slides. The heat fixed smear was then covered with crystal violet (primary stain) for one minute and the stain washed off with clean water. The smear was covered with iodine (mordant) and washed off with running water. The smear was covered with safranin (Secondary stain) for one minute and washed off with clean water. The back of the slide wiped with clean piece of cloth and placed on a rack and allowed to air dry. The stained slides were examined under the light microscope using the 100 objective lens with immersion oil.

Biochemical Characterization

The bacterial isolates were subjected to biochemical tests to aid their identification and characterization. The tests carried out included Indole, Methyl red, Voges–Proskauer (VP), Catalase, Citrate utilization, Urease and Motility tests, following the procedures described by Cheesbrough (2006).

pH and Temperature Analysis of Tiger Nut Drinks

The pH and temperature of selected tiger nut drink samples were determined to assess their physicochemical characteristics. The pH of each sample was measured using a digital pH meter, while temperature was determined using a Mercury in glass thermometer. The respective instruments were immersed directly into the samples, and the readings were recorded after stabilisation.

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Measurements were performed in triplicate to ensure consistency and reliability. The pH results were expressed as mean ± standard deviation, while temperature results were presented as mean values in degrees Celsius (°C).

Statistical Analysis

The data collected for analyses were entered and processed using the Statistical Package for the Social Sciences (SPSS). One-way Analysis of Variance (ANOVA) was used to evaluate differences in bacterial counts across sampling locations and between sample groups, where applicable. A probability value below 0.05 was regarded as statistically significant.

Results

From the analysis of the enteric bacterial population of Tiger nut and Tiger nuts Drinks samples obtained from the three selected markets are as presented in Table 1. The results revealed that, Oil Mill Market had the highest mean *Salmonella–Shigella* Count (SSC) of (13.96 ± 11.19 × 10^4 CFU/g), followed by samples collected from Rumuokoro Market (12.00 ± 12.30 × 10^4 CFU/g), while Mile 1 Market Tiger nuts samples had the lowest mean (6.95 ± 4.50 × 10^4 CFU/g). Similarly, the highest mean Total Coliform Count (TCC) was also recorded in samples from Oil Mill Market (11.86 ± 11.68 × 10^5 CFU/g), whereas the lowest was observed in samples from Mile 1 Market (10.50 ± 7.36 × 10^5 CFU/g). Differences among markets were not statistically significant for SSC and TCC ($p > 0.05$) as shown in Table 1. Tiger nuts Drinks obtained from Mile 1 Market had the highest mean SSC (2.67 ± 0.31 × 10^5 CFU/mL) and TCC (2.76 ± 0.05 × 10^6 CFU/mL). Samples obtained from eateries had the lowest mean SSC (0.83 ± 1.10 × 10^5 CFU/mL) and TCC (0.72 ± 0.46 × 10^6 CFU/mL). Differences among sampling points were statistically significant for SSC ($p = 0.021$) and TCC ($p < 0.001$) as shown in Table 1.

The prevalence of enteric bacteria in dried Tiger Nuts and Tiger Nut drink samples are as presented in Table 2. *Shigella* spp. was prevalent in all six samples from Mile 1 Market (100.0%) and in five samples each from Rumuokoro and Oil Mill markets (83.3% each). *Klebsiella* spp. was most prevalent in Rumuokoro Market (83.3%), whereas *Citrobacter* spp. and *Proteus* spp. were most prevalent in Oil Mill Market (66.7% each). *E. coli* and *Salmonella* spp. were not detected in the dried samples as shown in Table 2.

The fresh Tiger nut samples from Rumuokoro Market, *E. coli* had the highest prevalence (5/6; 83.3%), followed by *Proteus* spp. (4/6; 66.7%). In samples from Mile 1 Market, *Salmonella* spp. had the highest prevalence (4/6; 66.7%). In samples from Oil Mill Market, *Proteus* spp. was most prevalent (5/6; 83.3%), while *E. coli* was not detected. Overall, *Salmonella* spp. was detected in 10 of 18 fresh samples (55.6%) as shown in Table 2. The results obtained for the Tiger nut drinks samples showed that *Salmonella* spp. was detected in all three samples (100.0%) from each of the three markets, but was not detected in samples from eateries. *Shigella* spp. occurred in all samples from Rumuokoro Market and eateries (100.0%) and in two samples (66.7%) from each of Mile 1 and Oil Mill markets. *Citrobacter* spp. was detected in all three samples from Rumuokoro Market (100.0%). *Proteus* spp. was detected in two samples (66.7%) each from Mile 1 and Oil Mill markets, but was absent from samples from Rumuokoro Market and eateries as shown in Table 2.

Table 1: *Salmonella/Shigella* and Total Coliform Counts of the Tiger Nuts in the Three Markets

Location	Bacterial Counts (mean ± SD)			
	Tiger Nuts		Tiger Nut Drink	
	Salmonella/Shigella **(×10^4 CFU/g)**	**Total Coliform (×10^5 CFU/g)**	***Salmonella/Shigella*** **(×10^4 CFU/ml)**	**Total Coliform (×10^5 CFU/ml)**
Mile 1	6.95 ± 4.50	10.50 ± 7.36	2.67±0.31	2.76±0.05
Oil Mill	13.96 ± 11.19	11.86 ± 11.68	2.29±0.11	2.51±0.35
Rumuokoro	12.00 ± 12.30	10.73 ± 11.88	2.42±0.317	2.62±0.40
Eateries (n = 3)			0.83±1.10	0.72±0.46
p-value	0.470	0.972	0.021	0.001

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Table 2: Prevalence of Enteric Bacteria in Tiger Nuts Samples

Organism	Prevalence of Enteric Bacteria in Tiger Nut Samples									
	Fresh Tiger Nuts (N = 6), n (%)			Dried Tiger Nuts (N = 6), n (%)			Tiger Nut Drink (N = 3), n (%)			
	Rumuokoro	Mile 1	Oil Mill	Rumuokoro	Mile 1	Oil Mill	Rumuokoro	Mile 1	Oil Mill	Eateries
Salmonella spp.	3 (50)	4 (66.7)	3 (50)	0 (0.0)	0(0.0)	0(0.0)	3 (100.0)	3(100.0)	3(100.0)	0(0.0)
Citrobacter spp.	2 (33.3)	3 (50)	3 (50)	1 (16.7)	3 (50.0)	4 (66.7)	3(100.0)	2 (66.7)	1 (33.3)	1 (33.3)
E. coli	5 (83.3)	1 (16.6)	0	0(0.0)	0(0.0)	0(0.0)	1 (33.3)	2 (66.7)	1(33.3)	0 (0.0)
Klebsiella spp.	2 (33.3)	2 (33.3)	1 (16.6)	5 (83.3)	2 (33.3)	1 (16.7)	3 (100.0)	1 (33.3)	2 (66.7)	2 (66.7)
Proteus spp.	4 (66.7)	2 (33.3)	5 (83.3)	2 (33.3)	2 (33.3)	4 (66.7)	0 (0.0)	2 (66.7)	2 (66.7)	0 (0.0)
Shigella spp.	3 (50)	2 (33.3)	4 (66.7)	5 (83.3)	6 (100)	5 (83.3)	3 (100.0)	2 (66.7)	2 (66.7)	3 (100.0)

The results of the occurrence of enteric bacteria in dried Tiger Nuts and Tiger Nut drink samples are as presented in Table 3. The results obtained showed that *Shigella* spp. had the highest occurrence, being detected in 16 of 18 samples (88.9%). *Citrobacter* spp., *Klebsiella* spp. and *Proteus* spp. each occurred in eight samples (44.4%). Neither *E. coli* nor *Salmonella* spp. was recovered from the dried tiger nut samples as shown in Table 3

Table 3: Occurrence of enteric bacterial species in tiger nut samples

Bacterial species	Occurrence (%) of enteric bacteria in samples		
	Dried Tiger Nut	Fresh Tiger Nut	Tiger Nut Drinks
Citrobacter spp.	44.4	44.4	58.3
E. coli	0.0	33.3	33.3
Klebsiella spp.	44.4	27.8	66.7
Proteus spp.	44.4	61.1	33.3
Salmonella spp.	0.0	55.6	75.0
Shigella spp.	88.9	50.0	83.3

Twelve (12) processed Tiger Nut drink samples were examined: three each from Rumuokoro Market, Oil Mill Market, Mile 1 Market and eateries. A sample could yield more than one bacterial species. Six bacterial groups were isolated from the Tiger nuts drinks samples and their occurrence varies.

Shigella spp. had the highest occurrence in processed tiger nut drinks (83.3%), followed by *Salmonella* spp. (75.0%) and *Klebsiella* spp. (66.7%). *Citrobacter* spp. occurred in seven samples (58.3%), while *E. coli* and *Proteus* spp. each occurred in four samples (33.3%) as shown in Table 3. Six bacteria groups were isolated in the fresh Tiger nut samples, *Proteus* spp. had the highest occurrence (61.1%), followed by *Salmonella* spp. (55.6%) and *Shigella* spp. (50.0%). *Citrobacter* spp. occurred in eight samples (44.4%), *E. coli* in six samples (33.3%), while *Klebsiella* spp. had the lowest occurrence (5/18; 27.8%) as shown in Table 3.

The pH values of the selected tiger nut drink samples ranged from 6.85 ± 0.02 to 7.10 ± 0.01, while the recorded mean temperatures ranged from 25.7°C to 27.2°C as shown in Table 4.

Table 4: pH and Temperature of Selected Tiger Nut Drink Samples

Sample code	pH (Mean ± SD)	Temperature (°C, Mean)
2PR	6.85 ± 0.02	25.7
5PO	7.00 ± 0.01	25.9
9PM	7.02 ± 0.01	26.0
10PE	7.09 ± 0.00	26.2
11PE	7.10 ± 0.01	26.5
12PE	7.10 ± 0.00	27.2

Key: P = processed drink; R = Rumuokoro; O = Oil Mill; M = Mile 1; E = eatery. SD = Standard Deviation

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Discussion

The enteric bacterial load results showed that Tiger nut samples obtained from Mile 1, Oil Mill and Rumuokoro markets had no statistically significant differences in *Salmonella–Shigella* count or total coliform count ($p > 0.05$). Similarly, the differences between dried and fresh tiger nut samples were not statistically significant for either parameter. Although the mean counts varied between sample groups, the results suggest that the observed variations were not statistically significant. The recovery of Enteric bacterial from both dried and fresh tiger nuts is consistent with the findings of Ekong et al. (2024), who reported bacterial contamination in fresh and dried tiger nuts sold in Calabar. Their study also recovered organisms such as *Escherichia coli*, *Proteus* and *Klebsiella* species, although the bacterial profiles differed from those observed in the present study. The Tiger nut drinks showed statistically significant differences in *Salmonella Shige*lla Count and Total Colifom Count across the sampled locations ($p < 0.05$). The higher mean counts recorded in samples obtained from the markets compared with those obtained from eateries may reflect differences in processing, handling or storage conditions. However, these factors were not directly investigated in this study. The findings are comparable with those of Ire et al. (2020), who reported high microbial loads in ready-to-drink tiger nut beverages sold in Port Harcourt. Similarly, Eruteya et al. (2024) reported high total heterotrophic bacterial counts in vended tiger nut drinks sold in Choba, Rivers State. These findings highlight the need for improved hygienic practices during the preparation and vending of tiger nut drinks. The occurrence results showed that *Shigella* spp. had the highest occurrence in dried tiger nuts (88.9%), while *Citrobacter*, *Klebsiella* and *Proteus* spp. each recorded 44.4%. Neither *Salmonella* spp. nor *E. coli* was recovered from the dried samples. In fresh tiger nuts, *Proteus* spp. had the highest occurrence (61.1%), followed by *Salmonella* spp. (55.6%) and *Shigella* spp. (50%). The recovery of these organisms from fresh and dried samples suggests that drying, as represented by the samples examined, did not eliminate bacterial contamination. This is broadly consistent with Ekong et al. (2024), who also reported bacterial isolates from both wet and dry tiger nuts. However, the differences in the organisms recovered may reflect variations in sampling locations, handling conditions and microbial populations.

In processed tiger nut drinks, *Shigella* spp. recorded the highest occurrence (83.3%), followed by *Salmonella* spp. (75.0%) and *Klebsiella* spp. (66.7%). *Citrobacter* spp. occurred at 58.3%, while *E. coli* and *Proteus* spp. each recorded 33.3%. The recovery of these organisms is of public health concern because some members of these bacterial groups are associated with foodborne and gastrointestinal infections. Ire et al. (2020) similarly reported the presence of *Salmonella*, *Escherichia* and *Klebsiella* species in ready-to-drink tiger nut beverages sold in Port Harcourt. However, Eruteya et al. (2024) reported *Staphylococcus* and *Escherichia* species in vended tiger nut drinks from Choba. These findings demonstrate that the bacterial composition of tiger nut drinks may vary between locations and production sources.

The results of pH and Temperature analysis revealed that the pH of the selected tiger nut drinks ranged from 6.85 to 7.10, while the temperature ranged from 25.7°C to 27.2°C. The near-neutral pH values indicate that the samples did not have the acidic conditions that could inhibit the growth of many bacteria. This differs from the findings of Ire et al. (2020), who reported pH values of 4.2–4.6 in tiger nut drinks sold in Port Harcourt. Ejikeme et al. (2024) also reported acidic conditions in locally produced tiger nut drinks sold in Owerri. Differences in formulation, processing, fermentation and storage may contribute to variations in pH between studies. The temperatures recorded in the present study were within the ambient range; such conditions may permit bacterial survival and multiplication if the drinks are stored without refrigeration.

Conclusion

This study has established the occurrence of enteric bacteria in tiger nuts and their products obtained from different sampling locations in Port Harcourt, Rivers State, Nigeria. The bacterial species recovered were *Escherichia coli*, *Salmonella* spp., *Shigella* spp., *Klebsiella* spp., *Citrobacter* spp. and *Proteus* spp. indicating enteric bacterial contamination in dried Tiger nuts, fresh Tiger nuts and processed Tiger nuts drinks. The data obtained from the study showed The laboratory- washed and soaked prepared dried tiger nut samples recorded lower mean *Salmonella–Shigella* Count and Total Coliform Count than the fresh vended Tiger nuts sample that had higher counts in both

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Salmonella–Shigella Count and Total Coliform Count, although the differences were not statistically significant. The results showed that *Citrobacter* spp. was predominant in the dried tiger nut samples, *Proteus* spp. in the fresh tiger nut samples, and *Shigella* spp. in the tiger nut drink samples. The physicochemical assessment also revealed variations in the pH and temperature of the samples examined. These parameters provide additional information on the conditions of the products at the time of analysis and may influence microbial survival and growth.

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