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Chemical and Microbial Safety Assessment of Bambara, Gurasa, and Wara Sold Around Tertiary Institutions in Minna, Niger State, Nigeria

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Abstract

Indigenous ready-to-eat snacks, including Bambara (a fried Bambara-starch snack served with spiced pepper sauce), gurasa (a baked wheat-flour flatbread consumed with spiced fried pepper sauce and ground peanut/groundnut butter), and wara (a fried soybean-curd cheese, locally known as soy-wara or awara), are widely consumed by students in tertiary institutions in Minna, Niger State, Nigeria. Despite their popularity, limited empirical information exists regarding their chemical and microbiological safety within campus food environments. This study evaluated the levels of heavy metal contamination (lead, chromium, and cadmium) and microbial quality, including total bacterial, coliform, staphylococcal, and fungal counts, in these indigenous snacks sold around three tertiary institution communities in Minna. A total of ninety samples (30 per snack type; 10 samples per site across three locations) were collected and analysed in triplicate. Heavy metal concentrations were determined using Atomic Absorption Spectrophotometry (AAS), while microbial loads were quantified using the standard pour-plate technique. Lead was detected in 83.3% of Bambara samples (mean concentration: 0.144 ± 0.138 mg/L), compared with 26.7% and 40.0% detection frequencies in gurasa and wara, respectively. Chromium occurred in up to 93.3% of Bambara samples, with the highest mean concentration (1.692 ± 1.912 mg/L) recorded in gurasa. Overall, 18.9% of all samples exceeded the indicative lead benchmark of 0.3 mg/L, while 21.1% exceeded the indicative chromium benchmark of 2.0 mg/L. Cadmium concentrations remained below 0.2 mg/L in all samples. Microbiological analysis revealed fungal contamination in 48.9% of samples, total bacterial contamination in 32.2%, and *Staphylococcus aureus*-type colonies in 25.6%, with wara exhibiting the highest overall contamination rates. The predominant bacterial isolates were *Staphylococcus aureus* (44.4%) and *Bacillus subtilis* (26.7%), whereas *Saccharomyces cerevisiae* (60.0%), *Penicillium* spp. (28.9%), and the aflatoxigenic mould *Aspergillus flavus* (8.9%) were the dominant fungal isolates. The findings demonstrate that a substantial proportion of indigenous snacks sold around tertiary institutions in Minna pose both chemical and microbiological risks capable of compromising student health. The observed contamination patterns varied according to snack type and sampling location, underscoring the need for routine food safety surveillance, vendor education, strengthened hygiene practices, and effective enforcement of food safety regulations within campus food environments.

Keywords
Food safety;
Heavy metals;
Microbial contamination;
Bambara;
Wara;
Street vended food;
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1. Introduction

Foodborne disease remains a substantial and largely preventable public health burden. In its most recent global data synthesis, the World Health Organization Foodborne Disease Burden Epidemiology Reference Group (WHO FERG, 2026) reaffirmed that foodborne enteric, parasitic, and chemical hazards continue to cause hundreds of millions of illnesses annually, with the highest burden concentrated in Africa and South-East Asia. In response, the WHO Global Strategy for Food Safety 2022–2030 has called for strengthened national food-control systems and closer surveillance of informally traded foods, which remain a major but under-regulated route of exposure in low- and middle-income countries (World Health Organization [WHO], 2022).

Street vended and campus vended foods occupy a central place in the diets of Nigerian tertiary institution students because they are affordable, accessible, and culturally familiar. However, recent reviews describe the Nigerian street food sector as persistently underregulated, with weak enforcement of hygiene standards and limited vendor training (Mazi et al., 2023). Comparable assessments across Nigeria and neighbouring West African countries continue to report low food safety knowledge and inconsistent hygienic practice among vendors, including those operating close to schools, hospitals, and university campuses (Barnabas et al., 2024; Ibrahim et al., 2023; Nortey et al., 2024).

A systematic review and meta-analysis of ready to eat foods across developing countries similarly found bacteriological quality to be frequently unsatisfactory, with informally vended items posing a consistently elevated public health risk relative to formally regulated food outlets (Mengistu et al., 2022), while a systematic review of beverage related foodborne hazards in Nigeria documented substantial Staphylococcus and Salmonella contamination even in widely consumed fermented milk cereal drinks, underscoring that the country's informal food and beverage sector as a whole carries a persistent contamination burden (Oduori et al., 2022).

Among the snacks most frequently sold around Nigerian tertiary institutions are Bambara, prepared in this context as a fried Bambara starch snack eaten with a spiced pepper sauce, and derived from the drought tolerant legume Vigna subterranea, which is valued for its high protein and mineral content (Ramatsetse et al., 2022); gurasa, a baked wheat flour flatbread popular in northern Nigeria that is typically eaten with a spiced, oil fried pepper sauce and a garnish of ground peanut (groundnut) butter; and wara, here a fried soybean-curd cheese (also known as soy wara or awara), produced by coagulating boiled soymilk, moulding the curd, and frying it, rather than the more widely documented cow milk warankasi. These foods are attractive precisely because of the properties that also make them vulnerable to contamination. Although frying and baking impart an initial heat kill step, all three snacks are typically finished with raw or lightly processed condiments spiced pepper sauce, groundnut butter, or bare-handed moulding and slicing added after the main heat treatment and without further cooking, creating a plausible route for post process contamination.

Bambara products and groundnut-based garnishes such as the peanut butter used on gurasa are additionally susceptible to fungal

colonisation and aflatoxin accumulation during storage of the raw grains (Akullo, 2025; Poopola & Ehichioya, 2024), while wara, being a high moisture, near neutral pH curd product typically hawked without refrigeration after frying, remains intrinsically hospitable to bacterial regrowth on its surface.

Despite the scale of consumption, there is limited site-specific evidence on the chemical and microbial safety of these particular snacks as sold around tertiary institutions in Minna, Niger State. The present study was designed to close this gap. It was conceived, under a TETFund Institution Based Research proposal, as a 90 sample, investigation covering Bambara, groundnut, and wara. Sampling was conducted in Umaru Sanda Ahmadu College of Education Minna, the Bosso Campus of the Federal University of Technology Minna, and the School of Health Technology Minna and nearby communities. This paper reports the chemical (lead, chromium, cadmium) and microbiological (total bacterial, coliform, staphylococcal, and fungal counts, with organism level identification) results of the study as actually executed, and discusses their implications for food safety policy and practice on Nigerian tertiary institution campuses.

The specific objectives of the study were to:

1. Quantify lead, chromium, and cadmium concentrations in Bambara, gurasa, and wara sold around the study locations;
2. Determine the prevalence and load of total bacteria, coliforms, Staphylococcus type organisms, and fungi in the same samples;
3. Identify the dominant bacterial and fungal isolates recovered;
4. Compare contamination levels against indicative regulatory benchmarks to characterise the public health risk posed to the student population; and
5. Compare chemical and microbial contamination levels across the three sampling locations to identify whether particular campus communities carry a disproportionate food safety burden.

2. Materials and Methods

2.1 Study area and design

The study was carried out in Minna, the capital of Niger State, north-central Nigeria, a city that hosts a large concentration of tertiary institution students and associated informal food vending. A cross-sectional design was adopted, with sampling conducted at three community locations, each anchored to a tertiary institution: Location 1 (L1): Umaru Sanda Ahmadu College of Education, Minna, and its adjoining vending community; Location 2 (L2): the Bosso Campus of the Federal University of Technology, Minna, and its adjoining community; and Location 3 (L3): the School of Health Technology, Minna, and its adjoining community.

2.2 Sample collection

A total of 90 ready to eat snack samples were collected: 30 samples each of Bambara, gurasa, and wara, distributed as 10 samples per snack type at each of the three locations. Each sample was purchased directly from vendors operating around the respective institution, transported under cold chain conditions to the laboratory, and analysed in triplicate; the value reported for each sample is the mean of the triplicate determination. Samples were coded systematically by location, analysis type, snack, and serial number (for example, L1C/B1 for the chemical analysis of the first Bambara sample at Location 1, and L1M/B1 for the corresponding microbial analysis).

2.3 Chemical analysis

Lead (Pb), chromium (Cr), and cadmium (Cd) concentrations were determined using Atomic Absorption Spectrophotometry (AAS) following the water/air acetylene flame method. Samples were digested and analysed for each metal in mg/l, with a detection threshold below which a metal was recorded as not detected (ND). Concentrations below the instrument detection limit were treated as zero for the purpose of computing overall descriptive means.

2.4 Microbiological analysis

Microbial enumeration was carried out using the pour plate method. Total Bacterial Count (TBC), Total Coliform Count (TCC), Total Staphylococcus Count (TStC), and Total Fungal Count (TFC) were determined and expressed in colony forming units per gram (cfu/g); samples with no visible growth were recorded as No Growth (NG). Presumptive bacterial isolates were confirmed using standard biochemical tests, with additional acid tolerance and bile salt utilisation tests applied to presumptive lactic acid bacteria. Fungal isolates were identified by microscopy together with sugar fermentation and assimilation tests.

2.5 Data analysis

Descriptive statistics (mean, standard deviation, range) were computed for each metal and microbial parameter, by snack type, by sampling location, and overall. Detection/positivity frequencies are reported as counts and percentages. For heavy metals, sample concentrations were compared against indicative reference benchmarks commonly applied in the Nigerian and regional food safety literature 0.3 mg/l for lead, 0.2 mg/l for cadmium, and 2.0 mg/l for chromium (Mazi et al., 2023; Mwove et al., 2023) to estimate the proportion of samples of potential regulatory concern.

3. Results

3.1 Heavy metal contamination

Table 1 summarises lead, chromium, and cadmium concentrations across the three snack types. Lead was detected in 25 of 30 (83.3%) Bambara samples, with a mean concentration (including non-detects as zero) of 0.144 ± 0.138 mg/l and a maximum of 0.421 mg/l. Detection was markedly lower in gurasa (8/30, 26.7%) and wara (12/30, 40.0%), although when detected, lead concentrations in gurasa and wara were higher on average (0.533 mg/l and 0.427 mg/l among detected samples, respectively) than in Bambara (0.173 mg/l among detected samples), including a single gurasa sample reaching 2.101 mg/l.

Chromium was the most frequently and most heavily detected metal overall. It was found in 28 of 30 (93.3%) Bambara samples, 21 of 30 (70.0%) gurasa samples, and 9 of 30 (30.0%) wara samples, with mean concentrations (including non-detects) of 0.687 ± 0.435 mg/l, 1.692 ± 1.912 mg/l, and 0.653 ± 1.229 mg/l, respectively; gurasa samples reached a maximum of 4.457 mg/l. Cadmium was detected in all Bambara and gurasa samples (100%) but in only 12 of 30 (40.0%) wara samples; mean cadmium concentrations were low across all snacks (0.046 ± 0.018 mg/l in Bambara, 0.023 ± 0.013 mg/l in gurasa, 0.002 ± 0.003 mg/l in wara).

Against the indicative screening benchmarks, 17 of 90 samples (18.9%) exceeded the 0.3 mg/l lead benchmark, most frequently in wara (8/30, 26.7%), followed by Bambara (5/30, 16.7%) and gurasa (4/30, 13.3%). No sample exceeded the 0.2 mg/l cadmium benchmark.

For chromium, 19 of 90 samples (21.1%) exceeded the 2.0 mg/l benchmark, concentrated in gurasa (12/30, 40.0%) and wara (7/30, 23.3%), with no Bambara sample exceeding this threshold.

Table 1. Heavy metal concentrations (mg/l) in indigenous snacks sold around tertiary institutions in Minna (n = 30 per snack type)

Snack	Metal	Detection freq. n (%)	Mean ± SD (all samples)	Range (min–max)	% exceeding benchmark
Bambara	Pb	25 (83.3)	0.144 ± 0.138	0.000–0.421	16.7
	Cr	28 (93.3)	0.687 ± 0.435	0.000–1.481	0.0
	Cd	30 (100.0)	0.046 ± 0.018	0.027–0.100	0.0
Gurasa	Pb	8 (26.7)	0.142 ± 0.415	0.000–2.101	13.3
	Cr	21 (70.0)	1.692 ± 1.912	0.000–4.457	40.0
	Cd	30 (100.0)	0.023 ± 0.013	0.002–0.040	0.0
Wara	Pb	12 (40.0)	0.171 ± 0.259	0.000–0.926	26.7
	Cr	9 (30.0)	0.653 ± 1.229	0.000–4.230	23.3
	Cd	12 (40.0)	0.002 ± 0.003	0.000–0.009	0.0

Note: ND (not detected) values were treated as zero for computation of the mean and standard deviation. Benchmarks applied were 0.3 mg/l (Pb), 0.2 mg/l (Cd), and 2.0 mg/l (Cr), used as indicative screening values (see Section 2.5).

3.2 Microbial contamination

Table 2 presents the microbial quality of the three snack types. Total bacterial growth was observed most frequently in wara (15/30, 50.0%), followed by Bambara (8/30, 26.7%) and gurasa (6/30, 20.0%); overall, 29 of 90 samples (32.2%) showed detectable total bacterial counts, with positive samples averaging between 6,667 and 10,500 cfu/g depending on snack type. Total coliform counts were rare, appearing in only 3 of 90 samples overall (3.3%) and absent entirely from wara. Staphylococcus-type colonies were recovered from 23 of 90 samples (25.6%) overall, most frequently in wara (10/30, 33.3%). Fungal growth was the most common finding, occurring in 44 of 90 samples (48.9%) overall, and in more than half of both Bambara (16/30, 53.3%) and wara (17/30, 56.7%) samples.

Table 2. Microbial load of indigenous snacks sold around tertiary institutions in Minna (n = 30 per snack type)

Snack	Parameter	Positive n (%)	Mean cfu/g (positive samples)	Range cfu/g (positive samples)
Bambara	TBC	8 (26.7)	10,500	2,000–16,000
	TCC	1 (3.3)	2,000	—
	TStC	7 (23.3)	4,286	2,000–7,000
	TFC	16 (53.3)	3,000	1,000–6,000
Gurasa	TBC	6 (20.0)	6,667	3,000–15,000
	TCC	2 (6.7)	3,000	—
	TStC	6 (20.0)	2,667	2,000–6,000
	TFC	11 (36.7)	4,182	1,000–14,000
Wara	TBC	15 (50.0)	7,667	3,000–16,000
	TCC	0 (0.0)	—	—
	TStC	10 (33.3)	3,700	1,000–8,000
	TFC	17 (56.7)	4,824	1,000–10,000

TBC = Total Bacterial Count; TCC = Total Coliform Count; TStC = Total Staphylococcus Count; TFC = Total Fungal Count.

3.3 Bacterial and fungal isolates

Organism-level identification was carried out on 45 sub-samples with visible growth, drawn across the three snack types and locations. Among bacterial isolates (Table 3), *Staphylococcus aureus* was the most frequently recovered organism (20/45, 44.4%), followed by *Bacillus subtilis* (12/45, 26.7%). *Bacillus cereus*, *Micrococcus luteus*, and *Staphylococcus epidermidis* were each recovered in 5 of 45 sub-samples (11.1%), while *Lactobacillus fermentum* (4/45, 8.9%), *Klebsiella pneumoniae* (3/45, 6.7%), *Lactobacillus acidophilus* (2/45, 4.4%), and *Bacillus megaterium* (2/45, 4.4%) occurred less frequently.

Among fungal isolates (Table 4), *Saccharomyces cerevisiae* dominated, occurring in 27 of 45 sub samples (60.0%), consistent with its role as a natural fermentative organism in these products. *Penicillium species* were recovered in 13 sub samples (28.9%) and *Aspergillus niger* in 9 (20.0%). Mucor species were identified in 5 sub samples (11.1%), while the aflatoxigenic mould *Aspergillus flavus* was identified in 4 sub samples (8.9%), and *Aspergillus fumigatus* and *Rhizopus species* were each identified in 2 sub samples (4.4%).

Table 3. Frequency of bacterial isolates recovered from contaminated snack sub samples (n = 45)

Bacterial isolate	Frequency	% of sub samples (n = 45)
Staphylococcus aureus	20	44.4
Bacillus subtilis	12	26.7
Bacillus cereus	5	11.1
Micrococcus luteus	5	11.1
Staphylococcus epidermidis	5	11.1
Lactobacillus fermentum	4	8.9
Klebsiella pneumonia	3	6.7
Lactobacillus acidophilus	2	4.4
Bacillus megaterium	2	4.4

Table 4. Frequency of fungal isolates recovered from contaminated snack sub samples (n = 45)

Fungal isolate	Frequency	% of sub samples (n = 45)
Saccharomyces cerevisiae	27	60.0
Penicillium sp.	13	28.9
Aspergillus niger	9	20.0
Mucor sp.	5	11.1
Aspergillus flavus	4	8.9
Aspergillus fumigatus	2	4.4
Rhizopus sp.	2	4.4

3.4 Location specific analysis

Table 5 and Table 6 present chemical and microbial contamination pooled across all three snack types (n = 30 per location) at each of the three sampling locations: Location 1 (Umaru Sanda Ahmadu College of Education Minna and its adjoining vending community), Location 2 (the Bosso Campus of the Federal University of Technology Minna and its adjoining community), and Location 3 (the School of Health Technology Minna and its adjoining community).

Lead contamination was markedly higher around Locations 1 and 2 than around Location 3: lead was detected in 19 of 30 samples (63.3%) at Location 1 and 16 of 30 (53.3%) at Location 2, compared with 10 of 30 (33.3%) at Location 3, and the proportion of samples exceeding the 0.3 mg/l lead benchmark followed the same pattern (23.3% at both

Location 1 and Location 2, versus 10.0% at Location 3). Chromium showed the opposite gradient: detection and exceedance rose from Location 1 (16/30 detected, 53.3%; 10.0% exceeding the benchmark) through Location 2 (20/30, 66.7%; 23.3% exceeding) to Location 3 (22/30, 73.3%; 30.0% exceeding), which recorded both the highest chromium detection frequency and the highest chromium exceedance rate of the three locations. Cadmium detection was broadly similar across locations (76.7–83.3%), and no sample at any location exceeded the 0.2 mg/l cadmium benchmark.

At the snack within location level, the highest single cell lead means were recorded for gurasa at Location 1 (0.339 mg/l) and wara at Location 2 (0.262 mg/l), while the highest chromium means were recorded for gurasa at Location 2 (2.058 mg/l) and gurasa at Location 3 (2.049 mg/l), indicating that gurasa's chromium burden was consistently high wherever it was sampled.

Microbial contamination also varied by location, though less sharply than for the individual metals. Total bacterial counts were positive most often at Location 3 (11/30, 36.7%) and least often at Location 1 (8/30, 26.7%), while total coliform counts remained rare everywhere and were entirely absent at Location 2. Total Staphylococcus counts were broadly similar across locations (23.3–26.7% positive), and total fungal counts were highest at Location 2 (17/30, 56.7%) and lowest at Location 1 (13/30, 43.3%).

At the snack-within-location level, wara was the most consistently contaminated item at every location for total bacterial and staphylococcal counts (positive in 4–6 of 10 samples at each location), whereas fungal positivity was highest for Bambara at Location 2 (7/10) and for wara at Locations 2 and 3 (6/10 each).

Table 5. Heavy metal contamination by sampling location, pooled across all snack types (n = 30 per location)

Location	Metal	Detection freq. n (%)	Mean ± SD (all samples)	Range (min–max)	% exceeding benchmark
Location 1	Pb	19 (63.3)	0.239 ± 0.415	0.000–2.101	23.3
	Cr	16 (53.3)	0.603 ± 1.043	0.000–3.981	10.0
	Cd	24 (80.0)	0.022 ± 0.023	0.000–0.100	0.0
Location 2	Pb	16 (53.3)	0.156 ± 0.237	0.000–0.926	23.3
	Cr	20 (66.7)	1.192 ± 1.592	0.000–4.457	23.3
	Cd	25 (83.3)	0.024 ± 0.022	0.000–0.066	0.0
Location 3	Pb	10 (33.3)	0.063 ± 0.121	0.000–0.360	10.0
	Cr	22 (73.3)	1.237 ± 1.480	0.000–4.302	30.0
	Cd	23 (76.7)	0.024 ± 0.022	0.000–0.071	0.0

Location 1 = Umaru Sanda Ahmadu College of Education Minna community; Location 2 = FUT Minna, Bosso Campus community; Location 3 = School of Health Technology Minna community. Benchmarks as in Table 1.

Table 6. Microbial load by sampling location, pooled across all snack types (n = 30 per location)

Location	Parameter	Positive n (%)	Mean cfu/g (positive samples)
Location 1	TBC	8 (26.7)	9,250
	TCC	1 (3.3)	3,000
	TStC	8 (26.7)	3,500
	TFC	13 (43.3)	3,154
Location 2	TBC	10 (33.3)	8,500
	TCC	0 (0.0)	—
	TStC	7 (23.3)	4,286
	TFC	17 (56.7)	4,647
Location 3	TBC	11 (36.7)	7,273
	TCC	2 (6.7)	2,500
	TStC	8 (26.7)	3,125
	TFC	14 (46.7)	4,000

TBC = Total Bacterial Count; TCC = Total Coliform Count; TStC = Total Staphylococcus Count; TFC = Total Fungal Count.

4. Discussion

The location-specific results in Section 3.4 suggest that campus-adjacent vending communities are not uniformly at risk, and that the dominant hazard differs by site. Location 3 (School of Health Technology Minna) combined the lowest lead burden with the highest chromium burden and the highest total bacterial positivity of the three locations, whereas Locations 1 and 2 carried a comparatively heavier lead burden but a lighter chromium burden. Because gurasa's chromium contamination was consistently high at every location where it was sampled (means of 0.968–2.058 mg/l across the three sites), the location level chromium gradient most likely reflects differences in how much gurasa, and by extension its frying/griddle equipment, was represented in each location's vending mix, rather than a purely site-level environmental source such as soil or water. This pattern argues for vendor and equipment level rather than purely location level chromium surveillance in any follow-up study.

The near universal detection of chromium and, in Bambara, of lead is consistent with a growing body of Nigerian and regional evidence that

heavy metals routinely contaminate informally traded foods, most plausibly through contaminated soil and irrigation water, roadside dust deposition at open vending points, and the use of metal containing utensils and packaging during processing (Mazi et al., 2023; Mwove et al., 2023). The comparatively higher lead exceedance rate in wara (26.7%) than in the other snacks is noteworthy: because wara in this study is a soybean curd product (soy wara/awara) that is coagulated in open containers, moulded, and deep fried in reused vegetable oil before being hawked without refrigeration, it is exposed to several plausible contamination points the coagulation water, the moulding containers, and the frying oil and pan that could each introduce or concentrate metals such as lead and chromium.

All three snacks, being fried or baked in oil and then handled and served without further refrigeration, share a similar late-stage exposure pathway through cooking oil, utensils, and open air handling. That said, the very low cadmium levels recorded across all three snacks, all well below the indicative 0.2 mg/l benchmark, is a reassuring finding, and mirrors the generally low cadmium levels reported for other Nigerian and East African street vended foods (Mwove et al., 2023).

The absence of a single, universally agreed food category specific limit for chromium in the literature complicates interpretation of the 21.1% overall exceedance rate reported here; nevertheless, the sheer frequency and, in gurasa, the magnitude of chromium detection (mean 1.692 mg/l, maximum 4.457 mg/l) warrants closer scrutiny of stainless steel processing equipment, particularly griddles and frying implements, as a possible source, alongside soil and water contamination pathways already implicated in the wider Nigerian literature on heavy metals in street foods (Mazi et al., 2023).

On the microbiological side, the overall fungal positivity rate of 48.9%, together with the identification of *Aspergillus flavus* in 8.9% of contaminated sub samples, is consistent with reports that Nigerian groundnut and legume-based products are highly susceptible to aflatoxigenic mould colonisation, particularly under humid storage conditions (Akullo, 2025; Poopola & Ehichioya, 2024). A biotoxin profiling study of ready to eat foods vended in Lagos similarly detected mycotoxins and other fungal metabolites across a range of informally sold snacks, reinforcing that fungal contamination of Nigerian street vended foods is often accompanied by toxin production rather than being a purely cosmetic spoilage concern (Makinde et al., 2023). This risk pathway is directly relevant to gurasa as consumed in this study area, since the flatbread is customarily served with a garnish of ground peanut (groundnut) butter that is added raw after baking and receives no further heat treatment; any preexisting aflatoxin contamination in the groundnut garnish would therefore reach the consumer unmitigated.

While this study did not directly quantify aflatoxin B1 concentrations, the presence of *A. flavus* in Bambara and gurasa sub samples signals a latent mycotoxin risk that should be prioritised for direct toxin quantification in both the Bambara snack itself and the groundnut garnish used on gurasa in follow up work, given that aflatoxins have been reported in more than 80% of groundnut samples in some Nigerian markets, with a substantial

proportion exceeding NAFDAC's regulatory limit (Akullo, 2025).

The dominance of *Staphylococcus aureus* among bacterial isolates (44.4% of contaminated sub-samples) is a further concern. *S. aureus* is a well-recognized indicator of poor personal hygiene during food handling, and strains capable of producing heat stable enterotoxins can cause staphylococcal food poisoning even after the product has been reheated. Its frequent recovery here, together with the comparatively high total Staphylococcus counts and total bacterial counts observed in wara, echoes long-standing and more recent concerns about the microbiological safety of Nigerian soy-based wara/awara as a ready to eat, non-refrigerated, high moisture curd product that is typically handled, sliced, and moulded by hand after frying.

The second most frequent bacterial isolate, *Bacillus subtilis*, together with the related spore former *Bacillus cereus* recovered from 11.1% of contaminated sub samples, is also noteworthy: *Bacillus species* are ubiquitous, heat-resistant spore formers that can survive frying and baking and subsequently multiply during unrefrigerated display, with some strains capable of producing the emetic toxin cereulide or diarrhoeal enterotoxins (Yang et al., 2023). That vendor hygiene knowledge and practice remain inconsistent around Nigerian tertiary institutions has been documented directly: studies of food vendors and street-food handlers in Kano, in Nigeria's school feeding programme, and in comparable West African settings have repeatedly found gaps in food-safety knowledge, inadequate hand washing, and poor storage practice (Barnabas et al., 2024; Ibrahim et al., 2023; Nortey et al., 2024), and these behavioural gaps offer a plausible explanatory pathway for the contamination patterns observed in the present study.

Encouragingly, total coliform counts were rare across all three snacks (3.3% overall, and absent from wara), suggesting that gross faecal contamination of water or ingredients used in preparation was not a dominant problem at these particular vending points, even though other contamination indicators (total bacterial, staphylococcal, and fungal counts) were more frequently positive. This pattern suggests that interventions might usefully prioritise personal and surface hygiene during handling and storage where *S. aureus* and fungal contamination most plausibly originate over water source interventions alone.

Taken together, the chemical and microbial findings indicate that a meaningful minority to near-majority of the indigenous snacks examined depending on parameter and snack type carry hazards capable of contributing to acute foodborne illness (via S. aureus enterotoxins) or chronic exposure risk (via heavy metals and potential mycotoxins). Because these snacks are sold specifically around tertiary institution communities, the exposed population is large, repeat purchasing, and often price sensitive, characteristics that make behavioural and regulatory interventions targeted at campus adjacent vendors a potentially high value use of limited food safety resources.

5. Conclusion and Recommendations

This study found that indigenous snacks sold around tertiary institutions in Minna are

frequently, though variably, contaminated with heavy metals and microorganisms of public health significance. Chromium and, in Bambara, lead were detected at high frequency, with a fifth of all samples exceeding indicative screening benchmarks for both metals; cadmium contamination, by contrast, was consistently low. Microbiologically, fungal contamination affected nearly half of all samples, *Staphylococcus aureus* was the dominant bacterial isolate, and wara showed the highest overall microbial burden among the three snacks. The identification of the aflatoxigenic mould *Aspergillus flavus* in Bambara and gurasa sub samples flags a mycotoxin risk that warrants direct quantification in future work.

Recommendation

Based on these findings, the following actions are recommended:

1. Routine, institution-led microbial and chemical surveillance of snacks sold around campus vending points, with periodic public reporting of results;
2. Targeted hygiene and food-handling training for vendors operating near tertiary institutions, addressing the specific gaps in personal hygiene and safe storage repeatedly documented among Nigerian street-food vendors (Barnabas et al., 2024; Ibrahim et al., 2023);
3. Direct quantification of aflatoxin B1 in Bambara and gurasa products given the A. flavus isolation reported here;
4. Investigation of stainless-steel processing equipment and open-air vending practices as potential sources of chromium and lead contamination;
5. Strengthened routine inspection and enforcement at campus adjacent vending sites, since comparable Nigerian evidence shows that the great majority of street food vending sites are never inspected by health authorities and show low compliance with existing sanitary regulations (Alawode & Tabit, 2025); and
6. A follow up study with a larger, adequately powered sample size to validate and extend the present findings, including direct assessment of Salmonella and pathogenic *E. coli*. Implementing these measures would help protect the large and continually replenished population of tertiary institution students who rely on these indigenous snacks as an affordable and culturally valued part of their daily diet.

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