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Original Article

Heavy Metal Contamination and Microbial Quality of Ready-to-Eat Foods Sold in Motor Parks and Restaurants in Abakaliki, Nigeria

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ABSTRACT

Background: Commercially prepared foods may serve as sources of microbial and chemical contamination that threaten public health, particularly in environments with inadequate hygiene and environmental exposure.

Objective: This study assessed and compared the heavy metal contamination and microbial loads of cooked foods sold in motor parks and restaurants in Abakaliki, Ebonyi State, Nigeria.

Materials and Methods: Two commonly consumed ready-to-eat foods, rice with stew and African salad (Abacha), were obtained from three vendors each in Akubaraoha Central Park (open environment) and selected restaurants (enclosed environment) in Abakaliki. Heavy metals (zinc, copper, and lead) were analysed using Atomic Absorption Spectrophotometry after acid digestion, while microbial load was determined using the pour plate technique on Plate Count Agar. Data were analysed using one-way Analysis of Variance and Duncan's Multiple Range Test at $p < 0.05$ with SPSS version 22.0.

Results: Lead was not detected in any of the food samples analysed. Zinc and copper were present in all samples, with the highest zinc (51.9 mg/kg) and copper (17.5 mg/kg) concentrations recorded in Abacha obtained from restaurants. Significant differences in heavy metal concentrations were observed among the food samples ($p < 0.05$). The highest microbial load (3.1×10^5 cfu/g) was recorded in rice with stew obtained from restaurants, while the lowest (1.2×10^5 cfu/g) was observed in Abacha from restaurants. Microbial loads differed significantly among the samples ($p < 0.05$). As this exploratory study was based on a small number of vendors per food–location category, these findings should be interpreted as preliminary rather than representative of all ready-to-eat foods in Abakaliki.

Conclusion: The analysed food samples were free from detectable lead contamination, and zinc and copper concentrations were both within FAO/WHO permissible limits, indicating no immediate chemical safety concern from these metals in the samples assessed. Because heavy metals are environmentally persistent and capable of bioaccumulation, continued monitoring of commercially prepared foods is nonetheless warranted. The microbial counts obtained were within acceptable ranges but may indicate suboptimal hygiene and food handling practices. Improved food safety practices and regular monitoring of ready-to-eat foods are recommended to reduce potential public health risks.

Keywords: Food Contamination; Heavy Metals; Microbial Load; Ready-to-Eat Foods; Street Food

Introduction

Food contamination can occur at any stage of the food production chain, including production, processing, transportation, storage, preparation, and serving, and may render food unsafe for consumption [1]. However, food contamination remains a major public health concern worldwide, particularly in low- and middle-income countries where food handling and environmental sanitation practices are often inadequate. Contaminants may enter food during production, processing, transportation, storage, preparation, or serving, rendering such foods unsafe for consumption. These contaminants may originate from agrochemicals, environmental pollution of air, water, and soil, food packaging materials, industrial emissions, sewage discharge, vehicle exhaust fumes, and poor hygienic practices during food handling [2].

Food contamination may be chemical, microbial, parasitic, or physical in nature [4]. Among chemical contaminants, heavy metals are of particular concern because they are non-biodegradable, environmentally persistent, and capable of accumulating in biological systems over time [19,20]. Heavy metals such as lead, cadmium, arsenic, zinc, and copper may enter the food chain through contaminated soil, water, air, or food processing environments [14,15]. Chronic exposure to these metals has been associated with adverse health outcomes, including neurological disorders, renal impairment, cardiovascular disease, metabolic disturbances, and increased cancer risk [19–21]. Although zinc and copper are essential trace elements required for normal physiological functions, excessive intake may result in toxicity and disruption of metabolic processes [22]. Due to these health risks, the World Health Organization (WHO) and Food and Agriculture Organization (FAO) have established permissible limits for heavy metals in foods [23].

Microbial contamination of ready-to-eat foods is also a major cause of foodborne illness globally. Foodborne pathogens may remain undetected in contaminated foods because they often do not alter the taste, colour, or appearance of food products [5]. In 2010, contaminated foods were estimated to cause approximately 582–600 million cases of illness and more than 420,000 deaths worldwide, with the greatest burden occurring in Africa and Southeast Asia [6,7]. In many developing countries, street-vended and commercially prepared foods provide affordable and accessible meals for large populations but are frequently associated with poor hygiene, inadequate food safety knowledge, improper storage conditions, and microbial contamination [8].

In Nigeria, several studies have reported significant microbial contamination of ready-to-eat foods, including the presence of pathogenic organisms such as Escherichia coli, Staphylococcus aureus, and Salmonella species [9,10]. Poor environmental sanitation, inadequate regulation of food vending activities, and exposure of foods to dust, flies, and vehicular emissions contribute substantially to contamination risks [11,12]. Motor parks may represent particularly high-risk environments because foods are commonly prepared and sold in close proximity to heavy vehicular traffic and exhaust emissions containing metals such as lead, zinc, chromium, manganese, and copper [16–18]. In addition, environmental pollution associated with rapid urbanisation, poverty, and inadequate waste management further increases the likelihood of contamination of commercially prepared foods in many Nigerian cities [13–15].

Despite increasing concerns regarding food safety in Nigeria, limited data exist on the combined assessment of heavy metal contamination and microbial loads in ready-to-eat foods sold in different vending environments. Understanding the extent of contamination in foods sold in open environments such as motor parks compared with enclosed environments such as restaurants is important for evaluating potential public health risks and guiding food safety interventions. Therefore, this study assessed and compared the heavy metal contamination and microbial loads of cooked foods sold in motor parks and restaurants in Abakaliki, Ebonyi State, Nigeria. It was hypothesised that ready-to-eat foods sold in the open motor-park environment would show higher heavy metal and microbial contamination than those sold in enclosed restaurants, reflecting greater exposure to vehicular emissions, dust, and inconsistent hygiene conditions. Given the paucity of combined chemical–microbiological data for this specific food–vending context in southeastern Nigeria, this study was designed as an exploratory, small-scale pilot investigation intended to generate baseline evidence and inform the design of larger, adequately powered surveillance studies, rather than to provide population-representative contamination estimates. The findings may contribute to food safety awareness, nutrition education, and the development of public health strategies aimed at reducing contamination risks associated with commercially prepared foods.

Materials and Methods

Study Area

This study was conducted in Abakaliki, Ebonyi State, Nigeria, located within the derived savannah zone of southeastern Nigeria at latitude 06°19′ N and longitude 08°06′ E. The inhabitants are predominantly of the Igbo ethnic group, particularly the Afikpo–Abakaliki cultural subgroup. Akubaraoha Central Motor Park, one of the major transport hubs in Abakaliki, was selected as the open-environment sampling site. The motor park consists of multiple transport stations operated by different commercial bus companies and functions daily from approximately 4:30 am to 11:00 pm. In addition to transportation activities, the park serves as a major centre for commercial food vending, with several vendors selling cooked foods and beverages in close proximity to vehicular traffic. Selected restaurants within Abakaliki metropolis served as the enclosed environment sampling sites.

Study Design and Sample Collection

An experimental survey design was adopted for this study. Two commonly consumed ready-to-eat foods, rice served with tomato-based stew and African salad (Abacha), a traditional cassava-based delicacy commonly prepared with oil, vegetables, and fermented condiments, were purchased from food vendors operating within Akubaraoha Central Motor Park (open environment) and selected restaurants (enclosed environment) in Abakaliki. Three independent vendors were selected for each food category and sampling location using a convenience sampling approach based on vendor accessibility and willingness to participate; restaurants were included if they routinely served the target food items and consented to participate, and no formal random selection procedure was applied. The food samples were aseptically collected into sterile airtight containers, properly labelled, and transported immediately to the laboratory for analysis. The samples were coded as follows:

A1 = African Salad (Abacha) from motor park

A2 = African Salad (Abacha) from restaurant

B1 = Rice served with tomato-based stew from motor park

B2 = Rice served with tomato-based stew from restaurant

Mean values obtained from the three vendors in each category were used for analysis and comparison.

Determination of Heavy Metals

Heavy metal analysis was carried out using Atomic Absorption Spectrophotometry (AAS). Approximately 2.0 g of each homogenised food sample was weighed into a Kjeldahl digestion flask and digested with a mixture of concentrated sulphuric acid, perchloric acid, and nitric acid in a ratio of 1:4:40 (v/v/v), respectively. The mixture was allowed to stand overnight prior to digestion.

The samples were initially heated at 70 °C for approximately 40 minutes, after which the temperature was gradually increased to 120 °C until digestion was complete, indicated by the appearance of a clear solution with white fumes. The digest was cooled, diluted with 20 mL of distilled water, and boiled for 15 minutes. Thereafter, the solution was transferred into a 100 mL volumetric flask and made up to volume with distilled water. The resulting solution was filtered into labelled polyethylene bottles for analysis.

The concentrations of zinc (Zn), copper (Cu), and lead (Pb) were determined using an Alpha 4 Atomic Absorption Spectrophotometer (Chemtech Analytical, UK) equipped with hollow cathode lamps and a photomultiplier detector. Calibration curves were prepared using serial dilutions of 1000 ppm standard stock solutions of the respective metals. Heavy metal concentrations in the samples were determined by interpolation from the calibration curves, converted to a wet-weight mg/kg basis, and compared with FAO/WHO permissible limits for foods: Zn = 99.0 mg/kg, Cu = 40.0 mg/kg, and Pb = 0.30 mg/kg [23]. Formal analytical quality assurance measures — including reagent blanks, certified reference materials, spike-recovery experiments, and documented limits of detection and quantification — were not incorporated into this study; this is acknowledged as an analytical limitation in the Conclusions.

Microbial Analysis

Total viable bacterial counts were determined using the pour plate technique according to the American Public Health Association method. Approximately 10 g of each food sample was aseptically transferred into a sterile stomacher bag containing 90 mL of sterile 0.1% peptone water and homogenised for 2 minutes to obtain a 10^{-1} dilution.

Serial tenfold dilutions were subsequently prepared up to 10^{-5} by transferring 1 mL aliquots into 9 mL volumes of sterile 0.1% peptone water using sterile pipettes. For microbial enumeration, 1 mL aliquots from appropriate dilutions were aseptically inoculated into sterile Petri dishes, after which 15–20 mL of molten Plate Count Agar cooled to 45 ± 1 °C was added. The plates were gently swirled to ensure uniform mixing and allowed to solidify at room temperature.

The inoculated plates were incubated in an inverted position at 37 °C for 48 hours. Following incubation, plates containing 30–300 colonies were selected for counting using a digital colony counter.

Results were expressed as colony-forming units per gram (cfu/g) of sample using the formula:

cfu/g = (Number of colonies × dilution factor) ÷ volume plated (mL)

All microbial analyses were performed in triplicate, and mean values were recorded.

Statistical Analysis

All analyses were performed in triplicate, and results were expressed as mean ± standard deviation (SD). Formal tests of normality (e.g., Shapiro-Wilk) and homogeneity of variance (e.g., Levene's test) were not conducted prior to ANOVA; given the small sample size per group (n = 3), these assumptions could not be rigorously verified, and this is noted as a limitation. Data were analysed using one-way Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test for mean separation. Statistical significance was set at $p < 0.05$. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 22.0.

Ethical Approval

Ethical approval for the study was obtained from the Health Research Ethics Committee of Alex Ekwueme Federal University Teaching Hospital, Abakaliki (AE-FUTHA-HREC), with approval number NHREC/16/05/22.

Results

Table 1 presents the heavy metal concentrations of ready-to-eat foods obtained from motor parks and restaurants in Abakaliki, Ebonyi State, Nigeria. Lead was not detected in any of the analysed food samples. Zinc and copper were detected in all samples analysed.

The highest zinc concentration (51.9 mg/kg) was observed in African salad (Abacha) obtained from restaurants, followed by African salad from motor parks (48.7 mg/kg), rice served with tomato-based stew from restaurants (40.2 mg/kg), and rice served with tomato-based stew from motor parks (35.5 mg/kg). All zinc concentrations were below the FAO/WHO permissible limit of 99.0 mg/kg [23]. No significant difference was observed in zinc concentration between African salad obtained from motor parks and restaurants ($p > 0.05$). However, zinc concentration in African salad obtained from restaurants was significantly higher than that observed in rice with stew obtained from motor parks ($p < 0.05$).

Copper concentration was highest in African salad obtained from restaurants (17.5 mg/kg), followed by African salad from motor parks (14.8 mg/kg), rice with stew from restaurants (13.3 mg/kg), and rice with stew from motor parks (11.9 mg/kg). All copper concentrations were well below the FAO/WHO permissible limit of 40.0 mg/kg [23]. No significant difference was observed between copper concentrations in rice with stew obtained from restaurants and motor parks ($p > 0.05$). However, copper concentration in African salad obtained from motor parks was significantly higher than that of rice with stew obtained from restaurants ($p < 0.05$).

Table 1. Heavy Metal Concentrations of Ready-to-Eat Foods Sold in Motor Parks and Restaurants in Abakaliki, Nigeria

Heavy metals (mg/kg)	A1	A2	B1	B2	*p*-value
Zinc	$48.7^{a} \pm 1.4$	$51.9^{a} \pm 1.9$	$35.5^{c} \pm 2.8$	$40.2^{b} \pm 1.4$	< 0.001
Copper	$14.8^{b} \pm 0.6$	$17.5^{a} \pm 0.9$	$11.9^{c} \pm 0.6$	$13.3^{c} \pm 0.9$	< 0.001
Lead	ND	ND	ND	ND	-

A1: African salad (Abacha) from motor park
A2: African salad (Abacha) from restaurant
B1: Rice served with tomato-based stew from motor park
B2: Rice served with tomato-based stew from restaurant
Values are presented as mean ± SD (n = 3). Means within the same row bearing different superscript letters differ significantly at p < 0.05 using Duncan's Multiple Range Test.
ND = Not detected.

Table 2 shows the microbial loads of ready-to-eat foods obtained from motor parks and restaurants in Abakaliki. Microbial counts ranged from 1.2×10^5 cfu/g to 3.1×10^5 cfu/g. The highest microbial load (3.1×10^5 cfu/g) was observed in rice with stew obtained from restaurants, whereas the lowest microbial load (1.2×10^5 cfu/g) was recorded in African salad obtained from restaurants.

Rice with stew obtained from motor parks had a microbial load of 2.0×10^5 cfu/g, while African salad obtained from motor parks had a microbial load of 1.9×10^5 cfu/g. Statistical analysis showed significant differences in microbial loads among the food samples ($p < 0.05$).

Table 2. Microbial Loads of Ready-to-Eat Foods Sold in Motor Parks and Restaurants in Abakaliki, Nigeria

Samples	Food type	Microbial load (cfu/g) ± SD	*p*-value
A1	Abacha from motor park	$1.9^{c} \times 10^{5} \pm 0.04$	
A2	Abacha from restaurant	$1.2^{b} \times 10^{5} \pm 0.06$	
B1	Rice with stew from motor park	$2.0^{b} \times 10^{5} \pm 0.22$	<0.001
B2	Rice with stew from restaurant	$3.1^{a} \times 10^{5} \pm 0.30$	

Values are presented as mean ± SD (n = 3). Means within the same column bearing different superscript letters differ significantly at p < 0.05 using Duncan's Multiple Range Test.

Discussion

This study evaluated the heavy metal concentrations and microbial loads of selected ready-to-eat foods sold in motor parks and restaurants in Abakaliki, Ebonyi State, Nigeria. Zinc and copper were detected in all analysed food samples, whereas lead was not detected. The concentrations of zinc and copper were generally higher in African salad (Abacha) than in rice served with tomato-based stew. This observation may be associated with the composition and preparation methods of Abacha, which commonly involve vegetables, fermented condiments, palm oil, and fish. Fish and seafood products have previously been identified as important dietary sources of heavy metal exposure [25]. In addition, the soaking, fermentation, and washing processes involved in Abacha preparation may increase exposure to contaminated water and environmental pollutants. Foods sold in motor parks are frequently exposed to vehicular emissions, dust particles, and poor sanitary conditions, which may further contribute to contamination [16–18]. Previous studies have similarly reported that roadside ready-to-eat foods are more susceptible to contamination due to environmental exposure and poor food handling practices [24]. Although lead was not detected in this study, contrary to earlier reports from southeastern Nigeria [27–29], continuous monitoring remains necessary because heavy metals are environmentally persistent and capable of bioaccumulation [19,20]. Zinc and copper are essential trace elements involved in several metabolic processes; however, excessive exposure may result in adverse health effects [30,31]. In addition, environmental contaminants may enter the food chain through polluted soil and water sources used during food production and preparation [14,15]. Both zinc and copper concentrations in the analysed foods were below their respective FAO/WHO permissible limits (99.0 mg/kg and 40.0 mg/kg, respectively) [23], and the present data do not, on their own, indicate an immediate chemical safety hazard from these two metals. Nonetheless, because copper concentrations were highest in Abacha and because no dietary exposure or intake estimates (e.g., estimated daily intake, target hazard quotient) were calculated in this study, the cumulative contribution of these foods to total dietary copper exposure with frequent consumption remains an open question that warrants targeted follow-up. The zinc and copper concentrations recorded in this study fall within the general order of magnitude reported for ready-to-eat and market foods in other parts of Nigeria, where metal concentrations below regulatory limits have similarly been reported alongside occasional exceedances depending on food type, proximity to industrial or vehicular pollution sources, and analytical method [27–29]. This broad consistency suggests that low-level, sub-threshold heavy metal contamination is a recurring feature of Nigerian ready-to-eat foods rather than a phenomenon unique to Abakaliki, reinforcing the case for routine, harmonised monitoring rather than one-off assessments. From a food safety policy perspective, these findings support strengthened routine surveillance of vending sites (particularly motor parks), targeted vendor training on hygienic food handling and safe holding temperatures, and closer regulation of food preparation practices for dishes such as Abacha that involve extensive manual handling of raw ingredients; practical interventions could include mobile inspection units, vendor hygiene certification schemes, and public health messaging on safe food storage and reheating.

Microbial contamination was detected in all food samples irrespective of vending environment. Rice served with tomato-based stew obtained from restaurants had the highest microbial load, whereas African salad obtained from restaurants had the lowest count. The higher microbial counts observed in rice dishes may be related to prolonged holding temperatures, repeated exposure during serving, and inadequate storage conditions. African salad (Abacha) also demonstrated notable microbial contamination, particularly in samples obtained from motor parks. This may be associated with the use of raw vegetables, fermented condiments such as ugba and ogiri, contaminated water, and poor hygiene during food preparation and handling [26]. The microbial counts recorded in this study, based on total viable counts alone, suggest generally acceptable microbiological quality; however, because specific foodborne pathogens (e.g., Escherichia coli, Salmonella spp., Staphylococcus aureus, and Bacillus cereus) were not identified, total viable counts cannot on their own establish the presence or absence of foodborne illness risk. The relatively higher counts observed in some samples should be interpreted cautiously as a general indicator of hygiene status rather than direct evidence of pathogen contamination. These findings suggest that food type and vending environment were associated with differences in contamination levels and underscore the need for improved food safety practices among vendors of commercially prepared foods.

Conclusion

This exploratory study found detectable zinc and copper, and no detectable lead, in ready-to-eat foods sold in motor parks and restaurants in Abakaliki, Nigeria; both zinc and copper concentrations remained within FAO/WHO permissible limits. Food type and vending environment were associated with differences in contamination levels. Although microbial counts were within generally acceptable ranges, the relatively higher counts observed in some samples may indicate suboptimal hygiene and food handling practices. As no measured heavy metal concentration exceeded regulatory permissible limits, these findings did not trigger a formal reporting obligation to food safety regulatory authorities under current guidelines; the authors nonetheless intend to share these findings with relevant local health and environmental sanitation authorities in Abakaliki to support ongoing food safety monitoring. Overall, these findings highlight the value of regular monitoring of commercially prepared foods, improved vendor hygiene practices, and strengthened food safety regulations to reduce potential public health risks.

Limitations and Future Directions

This study has several limitations that should be considered when interpreting the findings. First, the small sample size (three vendors per food–location category) and restriction to two food types and a single motor park mean the results are exploratory and should not be generalised to all ready-to-eat foods sold in Abakaliki; seasonal variation in contamination was also not assessed, as sampling was conducted at a single time point. Second, vendors and restaurants were selected by convenience rather than random sampling, which may introduce selection bias. Third, microbial assessment was limited to total viable counts, without identification of specific foodborne pathogens such as Escherichia coli, Salmonella spp., Staphylococcus aureus, or Bacillus cereus; consequently, conclusions regarding foodborne illness risk should be interpreted cautiously. Fourth, formal analytical quality assurance procedures for heavy metal analysis — including certified reference materials, spike-recovery experiments, and documented limits of detection and quantification — were not incorporated, and formal statistical tests of normality and homogeneity of variance were not performed prior to ANOVA. Finally, no dietary exposure assessment (e.g., estimated daily intake or target hazard quotient) was conducted, limiting direct inference about health risk from the concentrations reported. Future studies should address these gaps by incorporating pathogen-specific microbial identification, formal analytical quality assurance and quality control procedures, probability-based sampling across a wider range of foods and vending sites, seasonal and year-round surveillance, and quantitative dietary exposure assessment, in order to better characterise contamination patterns and associated public health risks in Abakaliki and comparable Nigerian urban settings.

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