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Comparative Evaluation of Heavy Metal Concentrations in Selected Foods Processed Using Commercial Grinding Machines and Household Blenders in Lagos Island, Lagos State, Nigeria

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ABSTRACT

Heavy metal contamination of food through equipment-mediated pathways represents an under-studied but significant public health risk in rapidly urbanising Nigerian cities. This study aimed to determine the concentrations of lead (Pb), cadmium (Cd), and associated heavy metals in six selected foods processed using commercial grinding machines and household blenders in Lagos Island, Lagos State, and to compare heavy metal concentrations between the two equipment categories. A descriptive cross-sectional comparative design was employed, with 30 food samples collected across 18 commercial grinding machine sites and 12 household blender sites from seven market areas in Lagos Island. Ten heavy metals were analysed using a Shimadzu AA-7000 Atomic Absorption Spectrophotometer at Manzanita Research Laboratories, Ilorin. The results show that lead concentrations in commercially ground pepper ranged from 0.73 to 1.76 mg/kg, exceeding the World Health Organization (WHO) and Codex Alimentarius maximum permissible limit (MPL) of 0.3 mg/kg by up to 5.9 times. Lead was not detected in any household blender sample for egusi, ogbono, beans, and soyabeans. The Welch independent-samples t-test confirmed that commercial grinding machine samples had significantly higher mean lead concentrations (mean = 0.397 mg/kg) than household blender samples (mean = 0.028 mg/kg; $t = 4.030$, $df = 17.42$, $p = 0.001$). The estimated Hazard Quotient for lead was 0.69, representing 69% of the USEPA reference dose from this pathway alone. Arsenic was not detected in any sample. It is concluded that locally fabricated commercial grinding machines are a significant source of dietary lead contamination in Lagos Island. It is recommended that regulatory authorities enforce mandatory food-contact surface safety standards for commercial grinding equipment.

Keywords: Heavy metals, Lead, Commercial grinding machines, Food safety, Lagos Island, Hazard Quotient

INTRODUCTION

Food safety is a critical determinant of public health outcomes in rapidly urbanising societies, where the risk of chemical contamination is compounded by inadequate regulatory oversight, widespread use of informally fabricated food processing equipment, and limited consumer awareness. Among the most persistent categories of chemical food contaminants, heavy metals particularly lead (Pb) and cadmium (Cd) pose singular public health concern because of their environmental persistence, bioaccumulative nature, and irreversible toxicity at trace dietary concentrations (Rai *et al*., 2019; Jaishankar *et al*., 2014).

Lead is classified as a Group 2A probable human carcinogen by the International Agency for Research on Cancer (IARC, 2023), with no established safe threshold for neurotoxicity in children. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) has withdrawn the Provisional Tolerable Weekly Intake for lead, citing the impossibility of identifying a safe intake level (Magnano and Larese Filon, 2024). Cadmium, a Group 1 carcinogen with a biological half-life of 16 to 30 years, accumulates progressively in the renal cortex and produces irreversible nephrotoxicity at relatively low cumulative exposures (Charkiewicz *et al*., 2025; Kim *et al*., 2024).

A largely uncharacterised dietary exposure pathway in Nigerian urban markets is equipment-mediated heavy metal contamination the direct transfer of metals from food processing machinery into the food matrix during the grinding or blending process. Commercial grinding machines operating in Lagos Island markets are predominantly fabricated from mild steel and ungraded metallic alloys without any regulatory certification of food-contact surface composition. The combination of mechanical abrasion by which rotating grinding surfaces dislodge metallic microparticles into food and corrosive acid dissolution by which organic acids in food substrates dissolve lead and other metals from equipment surfaces creates conditions highly favourable to dietary heavy metal exposure through this pathway (Rossi *et al*., 2024; Hossain *et al*., 2024). Acidic food substrates such as pepper (Capsicum frutescens) are particularly potent drivers of corrosive metal dissolution, given their pH of approximately 4.5 to 5.5.

The scale of this problem in Lagos Island is substantial. Lagos Island Local Government Area (LGA) is one of the most densely populated localities in sub-Saharan Africa, hosting major commercial markets Sandgrouse, Ita-Faji, Adeniji, Isale-Eko, Idumota, Oshodi, and Beecroft where commercial grinding machines process millions of food portions daily for a population that relies on communally processed food as a daily dietary staple. Six food matrices are routinely processed through these machines: egusi melon seeds (Citrullus lanatus), ogbono kernels (Irvingia gabonensis), pepper (Capsicum frutescens), maize-based porridge (Zea mays), beans (Vigna unguiculata), and soyabeans (Glycine max). Despite the documented concern about heavy metal contamination from such equipment by food safety scientists and Nigerian legislators (African Health Report, 2026), no peer-reviewed study has systematically characterised this pathway with a balanced comparative design for Lagos Island.

Regulatory frameworks for heavy metals in food are anchored in the Codex Alimentarius General Standard for Contaminants and Toxins in Food and Feed (CXS 193-1995, Rev. 2024), which sets MPLs of 0.3 mg/kg for lead and 0.2 mg/kg for cadmium in most processed food commodity categories. In Nigeria, the National Agency for Food and Drug Administration and Control (NAFDAC) and the Standards Organisation of Nigeria (SON) are mandated to enforce food safety standards; however, practical enforcement of food-contact surface safety in the informal grinding machine sector remains absent. Studies from Port Harcourt (MedCrave, 2018) and Kaduna (Saulawa and Jikamshi, 2024) have documented dietary lead and cadmium exposures in Nigerian urban market foods, but none has specifically attributed contamination to the grinding machine pathway through a controlled comparative study with household blenders as the reference category.

Therefore, the aim of this study is to comparatively evaluate heavy metal concentrations in selected foods processed using commercial grinding machines and household blenders in Lagos Island, Lagos State, Nigeria. The specific objectives are: (1) to determine the concentrations of lead (Pb), cadmium (Cd), and associated heavy metals in foods processed by commercial grinding machines and household blenders across Lagos Island; and (2) to compare mean lead and iron concentrations between foods processed by commercial grinding machines and those processed by household blenders, and to assess the associated non-carcinogenic health risk.

MATERIALS AND METHODS

Study Area

The study was conducted in Lagos Island Local Government Area, Lagos State, Nigeria. Lagos Island is situated at approximately latitude 6°26'N and longitude 3°23'E, occupying approximately 7.9 km² on a small island in the Lagos Lagoon, bounded by Lagos Harbour to the south, Five Cowrie Creek to the west,

and the broader Lagos Lagoon to the north and east. Lagos Island is the historic commercial nucleus of Lagos State and, by extension, Nigeria, hosting major food markets including Balogun, Idumota, Sandgrouse, Ita-Faji, Isale-Eko, and Adeniji, where commercial food processing particularly grinding and blending constitutes a central daily economic activity serving the residential population of Lagos Island and surrounding areas. The study area is characterised by a tropical wet climate with mean annual rainfall of approximately 1,600 mm, predominantly occurring between April and October. The food sampling and data collection activities were conducted during June and July 2026.

Procedures

A purposive sampling technique was employed to select commercial grinding machine sites and household blender participants from across Lagos Island. The study encompassed seven commercial market areas Sandgrouse, Ita-Faji, Adeniji, Oshodi, Isale-Eko, Idumota, and Beecroft and two residential household blender locations Aroloya and Onikan. Six food matrices were selected for analysis: egusi (Citrullus lanatus), ogbono (Irvingia gabonensis), pepper (Capsicum frutescens), maize pap (Zea mays), beans (Vigna unguiculata), and soyabeans (Glycine max). A total of 30 food samples were collected: 18 from commercial grinding machine sites (three sites per food matrix across six matrices) and 12 from household blender sites (two sites per food matrix across six matrices). All food samples were collected directly from the processing equipment immediately after completion of a grinding or blending cycle, using pre-cleaned acid-washed high-density polyethylene (HDPE) sampling containers. A structured questionnaire was administered to 30 respondents comprising commercial grinding machine operators and household blender users to obtain socio-demographic and equipment-use data. Samples were transported in a cool box at approximately 4°C to Manzanita Research Laboratories, Ganmo, Kwara State, and received within 24 hours of collection.

Determination of Heavy Metal Concentrations

All laboratory analyses were conducted at Manzanita Research Laboratories, Ganmo, Kwara State, Nigeria (Prepared by: Dr. Olakunle Ayanda, Managing Director). Approximately 3 grams of each homogenised food sample was digested using a wet acid digestion procedure: 10 mL of concentrated sulphuric acid (H_2SO_4) and 5 mL of concentrated nitric acid (HNO_3) were added to the sample in a digestion tube and heated on a block digester until the volume was reduced to approximately 2 mL and the solution became colourless. The digested solution was neutralised by dropwise addition of 1 M sodium hydroxide (NaOH), filtered through Whatman filter paper No. 42, and diluted to the mark in a 25 mL volumetric flask.

Ten heavy metals lead (Pb), cadmium (Cd), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), chromium (Cr), nickel (Ni), cobalt (Co), and arsenic (As) were determined using a Shimadzu AA-7000 Atomic Absorption Spectrophotometer. Results were reported in milligrams per kilogram (mg/kg) dry weight. Concentrations below the method detection limit were recorded as Not Detected (ND) and substituted with 0.005 mg/kg (half the detection limit) for statistical computation. Quality assurance and quality control (QA/QC) measures included calibration against certified aqueous reference standards with correlation coefficients ≥ 0.999, procedural reagent blanks with every batch, spike recovery experiments (85–115% acceptance range), field blank samples, and field duplicate samples (relative percent difference < 8%). A certified reference material (BCR® 191 Mixed Vegetables) was analysed with each batch; measured concentrations fell within ±8% of certified values.

Determination of Non-Carcinogenic Health Risk

Non-carcinogenic health risk was assessed using the United States Environmental Protection Agency (USEPA) Hazard Quotient (HQ) framework. The Estimated Daily Intake (EDI) was calculated as:

$$\mathbf{EDI = (C \times IR) / BW}$$

where C = mean metal concentration in commercially ground food (mg/kg), IR = daily ingestion rate (kg/day), and BW = body weight (kg). The Hazard Quotient was calculated as:

$$\mathbf{HQ = EDI / RfD}$$

where RfD is the USEPA oral reference dose (Pb: 0.0036 mg/kg/day; Cd: 0.001 mg/kg/day). A reference body weight of 60 kg (Nigerian adult) was used. An HQ ≥ 1.0 indicates that the estimated exposure

exceeds the tolerable intake level. Ingestion rates were: pepper 0.05 kg/day; maize pap 0.20 kg/day; egusi, ogbono, beans, and soyabeans 0.03 kg/day each.

Statistical Tools Used

Data were coded and entered into Microsoft Excel (version 2021) for initial organisation and verification, then subjected to descriptive and inferential statistical analysis using IBM SPSS Statistics (version 26). Descriptive statistics including mean, standard deviation (SD), minimum, and maximum were computed for all metals across each food matrix and equipment category. Levene's test was applied to verify the assumption of variance homogeneity, and the Shapiro-Wilk test was used to assess normality of distribution. The Welch independent-samples t-test was applied to compare mean lead (Pb) and iron (Fe) concentrations between commercial grinding machine and household blender food samples, given the confirmed inequality of variances between groups. Effect size was quantified using Cohen's d. A 95% confidence interval (CI) for the difference in means was calculated. The significance level was set at $\alpha = 0.05$. Detected concentrations were compared against WHO/FAO Codex Alimentarius MPLs to determine the pattern and proportion of exceedances.

RESULTS

Table 4.1: Socio-demographic Profile of Respondents (N = 30)

Variables	Level	Count	Percentage (%)
Gender	Male	22	73.3%
	Female	8	26.7%
	Total	30	100%
Age Group	20–30 years	10	33.3%
	31–40 years	14	46.7%
	41 years and above	6	20.0%
	Total	30	100%
Occupation	Commercial Grinding Machine Operator	18	60.0%
	Household Blender User	12	40.0%
	Total	30	100%
Years of Operation	Less than 2 years	8	26.7%
	2 to 5 years	12	40.0%
	More than 5 years	10	33.3%
	Total	30	100%
Cleaning Frequency (CGM operators)	Daily	6	33.3%
	Weekly	9	50.0%
	Monthly or less	3	16.7%
	Total (CGM)	18	100%

CGM = Commercial Grinding Machine.

Table 4.1 shows the socio-demographic characteristics of the 30 respondents. The majority were males (73.3%), while females accounted for 26.7%. Respondents aged 31–40 years (46.7%) constituted the largest age group. Commercial grinding machine operators accounted for 60.0%, while household blender users were 40.0%. Regarding years of operation, 40.0% had operated for 2–5 years. Among CGM

operators, 50.0% cleaned their machines weekly, while 33.3% cleaned them daily and 16.7% monthly or less.

Table 4.2: Classification of Food Processing Equipment Type (N = 30)

Equipment Category	Count	Percentage (%)
Commercial Grinding Machine (CGM)	18	60.0%
Household Blender (HB)	12	40.0%
Total	30	100%

Table 4.2 presents the classification of food processing equipment used by the respondents. Commercial Grinding Machines (CGM) constituted the majority, with 18 (60.0%) respondents, while 12 (40.0%) used Household Blenders (HB). This shows that CGMs were more commonly used for food processing among the respondents, accounting for three-fifths of the equipment assessed.

Table 4.3: Characteristics of Food Processing Equipment and Sampling Sites

Food Matrix	Commercial Grinding Machine Sites	HB Sites	Total Samples
Egusi (Citrullus lanatus)	Sandgrouse, Ita-Faji, Adeniji	Aroloya, Onikan	5
Ogbono (Irvingia gabonensis)	Sandgrouse, Ita-Faji, Oshodi	Aroloya., Onikan	5
Pepper (Capsicum frutescens)	Isale-Eko, Idumota, Ita-Faji	Aroloya., Onikan	5
Maize Pap (Zea mays)	Isale-Eko, Oshodi, Beecroft	Aroloya, Onikan	5
Beans (Vigna unguiculata)	Sandgrouse, Ita-Faji, Adeniji	Aroloya, Onikan	5
Soyabeans (Glycine max)	Sandgrouse, Ita-Faji, Oshodi	Aroloya, Onikan	5
TOTAL	18 samples	12 samples	30

HB = Household Blender. Lagos Island Est. = Lagos Island Estate.

Table 4.3 presents the distribution of the 30 food samples collected from different food processing equipment and sampling sites. Six food matrices-egusi, ogbono, pepper, maize pap, beans, and soybeans-were assessed, with five samples collected for each food type. Commercial Grinding Machine (CGM) sites contributed 18 samples, while Household Blender (HB) sites contributed 12 samples. The samples were obtained from various locations within Lagos Island, providing coverage of different processing sites and food matrices for subsequent laboratory analysis.

Table 4.4: Heavy Metal Concentrations in Foods Processed by Commercial Grinding Machines and Household Blenders (mg/kg dry weight)

Food Matrix	WHO MPL	HB: Lagos Island Est.	HB: Onikan	CGM Site 1	CGM Site 2	CGM Site 3	WHO MPL Exceedance?
Egusi Pb	0.3	ND	ND	0.24	**0.32***	0.29	Yes (1 of 3)
Egusi Fe	48.0	37.80	34.60	**68.30***	**50.80***	42.90	Yes (2 of 3)
Egusi Cd	0.2	ND	ND	ND	0.01	ND	No
Pepper Pb	0.3	0.09	0.08	**0.84***	**1.76***	**0.73***	Yes (3 of 3)

Pepper Fe	48.0	**55.40***	**53.60***	**144.60***	**121.30***	**114.70***	Yes (all 5)
Pepper Cd	0.2	ND	ND	ND	0.02	ND	No
Maize Pb	0.3	0.07	0.06	**0.42***	0.24	0.30	Yes (1 of 3)
Beans Pb	0.3	ND	ND	0.22	0.26	0.21	No
Soyabeans Pb	0.3	ND	ND	0.18	0.23	0.20	No
All matrices As	0.1	ND	ND	ND	ND	ND	No

** = value exceeds WHO/FAO Codex Alimentarius MPL. ND = Not Detected. HB = Household Blender. CGM = Commercial Grinding Machine. CGM Site 1/2/3 vary by food matrix (see Table 4.3). Ogbono Pb (range 0.19–0.28 mg/kg, all below MPL) not shown separately; full data in supplementary material. Source: Manzanita Research Laboratories (2026).*

Table 4.4 presents the concentrations of selected heavy metals in foods processed using Commercial Grinding Machines (CGMs) and Household Blenders (HBs), compared with the WHO maximum permissible limits (MPLs). Lead (Pb) exceeded the permissible limit in some egusi, pepper and maize samples, with the highest concentration recorded in pepper at 1.76 mg/kg. Iron (Fe) also exceeded the WHO limit in some egusi samples and all pepper samples, with the highest value of 144.60 mg/kg. Cadmium (Cd) and arsenic (As) were generally not detected or remained below the specified limits.

Table 4.5: Statistical Comparison of Lead (Pb) and Iron (Fe) Concentrations between Commercial Grinding Machine and Household Blender Food Samples

Metal	n(CGM)	Mean CGM (mg/kg)	Mean HB (mg/kg)	95% CI (difference)	t-stat	df	p-value
Lead (Pb)	18	0.397 ± 0.385	0.028 ± 0.035	[0.181, 0.556]	4.030	17.42	0.001
Iron (Fe)	18	67.44 ± 29.84	37.73 ± 9.22	[12.28, 47.14]	3.816	13.88	0.002

Mean values expressed as Mean ± SD. n(HB) = 12 for both metals. p-values are one-tailed (directional hypothesis: CGM > HB). Cohen's d: Pb = 1.223 (large effect); Fe = 0.944 (large effect). CGM = Commercial Grinding Machine. HB = Household Blender.

Table 4.5 shows a statistically significant difference in the concentrations of lead (Pb) and iron (Fe) between food samples processed using Commercial Grinding Machines (CGMs) and Household Blenders (HBs). The mean Pb concentration was significantly higher in CGM samples (0.397 ± 0.385 mg/kg) than in HB samples (0.028 ± 0.035 mg/kg), with $p = 0.001$. Similarly, mean Fe concentration was significantly higher in CGM samples (67.44 ± 29.84 mg/kg) than in HB samples (37.73 ± 9.22 mg/kg), with $p = 0.002$. These findings indicate that CGM-processed food samples had significantly higher Pb and Fe concentrations than HB-processed samples.

Table 4.6: Estimated Daily Intake (EDI) and Hazard Quotient (HQ) for Lead (Pb) and Cadmium (Cd) from Commercially Ground Food (mg/kg/day)

Food Matrix/Metal	Mean Conc. (mg/kg)	IR (kg/day)	BW (kg)	EDI (mg/kg/day)	RfD (mg/kg/day)	HQ
Pepper Pb	1.110	0.05	60	0.000925	0.0036	—
Maize Pap Pb	0.320	0.20	60	0.001067	0.0036	—
Egusi Pb	0.283	0.03	60	0.000142	0.0036	—
Ogbono Pb	0.233	0.03	60	0.000117	0.0036	—
Beans Pb	0.230	0.03	60	0.000115	0.0036	—
Soyabeans Pb	0.203	0.03	60	0.000102	0.0036	—
TOTAL LEAD (Pb)	—	—	60	**0.002468**	0.0036	**0.69**
Pepper Cd	0.020	0.05	60	0.000017	0.001	—
Maize Pap Cd	0.030	0.20	60	0.000100	0.001	—
TOTAL CADMIUM (Cd)	—	—	60	**0.000117**	0.001	**0.12**

IR = daily ingestion rate (kg/day). BW = body weight (60 kg, Nigerian adult reference). RfD = USEPA oral reference dose. HQ = EDI/RfD; HQ ≥ 1.0 indicates potential health concern. EDI = (C × IR) / BW. Source: USEPA IRIS (2023).

Table 4.6 presents the estimated daily intake (EDI) and hazard quotient (HQ) for lead (Pb) and cadmium (Cd) from commercially ground food samples. The total EDI for Pb was 0.002468 mg/kg/day, giving an HQ of 0.69, while Cd had a total EDI of 0.000117 mg/kg/day and an HQ of 0.12. Both HQ values were less than 1, indicating that the estimated exposure to Pb and Cd through consumption of the assessed food samples does not suggest a significant non-carcinogenic health risk under the assumptions used. Among the foods assessed, maize pap recorded the highest EDI for Pb (0.001067 mg/kg/day), while its Cd EDI was 0.000100 mg/kg/day.

DISCUSSION

The study found that males constituted the majority of respondents (73.3%), while commercial grinding machine operators accounted for 60.0%. Half of the commercial grinding machine operators reported weekly cleaning, whereas only 33.3% cleaned their machines daily. This pattern is important because inadequate cleaning and prolonged use may allow food residues and contaminants to accumulate on processing surfaces. Previous Nigerian studies have similarly identified mechanical milling and grinding equipment as potential sources of heavy-metal contamination in food, particularly where metallic components are subject to wear and repeated use.

Lead contamination was particularly pronounced in pepper processed with commercial grinding machines, with concentrations of 0.73–1.76 mg/kg, exceeding the permissible limit of 0.3 mg/kg. Lead also exceeded the limit in one egusi and one maize sample. Iron concentrations similarly exceeded the specified limit in two egusi samples and all pepper samples, reaching 144.60 mg/kg. These findings are consistent with Nnaji *et al*., who reported enrichment of foodstuffs with Pb and Fe following processing with metallic grinding machines in Umuahia. They are also consistent with Asere's findings that mechanical milling could introduce heavy metals into food, with iron generally occurring at higher concentrations than lead and cadmium.

The significantly higher mean concentrations of lead and iron in commercial grinding machine samples compared with household blender samples (p = 0.001 and p = 0.002, respectively) further support previous evidence that processing equipment can influence metal levels in food. Nnaji *et al*. similarly

found higher metal concentrations in foodstuffs processed with metallic grinders than in control samples processed without metallic grinding equipment. Aremo *et al*. also investigated corrosion of metallic components of wet grinding machines and demonstrated the potential for metal contamination of processed pepper and maize. However, the present findings should be interpreted as an association, since factors such as food characteristics, equipment condition, cleaning practices and processing frequency may also influence contamination.

The exposure assessment showed a total lead EDI of 0.002468 mg/kg/day and an HQ of 0.69, while cadmium recorded an EDI of 0.000117 mg/kg/day and an HQ of 0.12. Both HQ values were below 1.0, suggesting that the estimated exposure through the assessed pathway did not indicate an apparent non-carcinogenic risk under the assumptions of the study. This differs from the findings of Nnaji *et al*., who reported health-risk indices above one for some metals and foodstuffs processed with metallic grinders in Umuahia. The difference may be related to variations in metal concentrations, food types, consumption assumptions and characteristics of the grinding equipment used in the two studies.

CONCLUSION

The study concludes that food-processing equipment, particularly commercial grinding machines, may contribute to heavy-metal contamination of processed foods in Lagos Island. Lead and iron were the major metals of concern, with some samples, especially commercially processed pepper, exceeding the permissible limits. Commercial grinding machine samples also recorded significantly higher mean concentrations of lead and iron than household blender samples.

Although the estimated hazard quotients for lead (0.69) and cadmium (0.12) were below 1.0, indicating no apparent non-carcinogenic risk from the assessed exposure pathway, the presence of elevated metal concentrations in some food samples remains a public health concern. The findings therefore highlight the importance of proper cleaning, regular maintenance and monitoring of commercial food-processing equipment to minimise heavy-metal contamination and protect consumers.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Commercial grinding machine operators should improve cleaning practices, with equipment cleaned thoroughly after each day's operation to minimise the accumulation of food residues and potential contaminants.
2. Regular inspection and maintenance of commercial grinding machines should be enforced, particularly the replacement of worn or corroded metallic components.
3. Environmental health and regulatory authorities should conduct periodic monitoring of processed foods and grinding equipment for heavy-metal contamination and ensure compliance with established permissible limits.
4. Operators should be educated on food safety and equipment hygiene to reduce potential heavy-metal contamination and protect consumers.

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