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Human Health Risk Assessment of Heavy Metals, and Bacteriological Analysis of Cassava Flakes (Garri) Sold in Major Markets in Makurdi Metropolis, Benue, Nigeria

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ABSTRACT

Today, food safety is a global primary priority determinant, surpassing nutritional quality and cost, in foods choices. Contaminants such as bacteria and heavy metals are regarded as highly disturbing and of primary health concern. This study examines the quality of road side sold cassava flakes in Makurdi. Samples from five major markets were analyzed using Flame Atomic Absorption Spectroscopy, for the respective heavy metals: Pb, Cd, Cr, Ni, Cu and Zn. And subsequently their potential human health risk: Daily intake of metals (DIM), Health risk index (HRI), Target hazard quotient (THQ) and Total target hazard quotient (TTHQ). Plate count bacteriological analysis was employed. In this study, Cd, Cu and Zn were detected in the respective mg/kg ranges; 1.00 - 2.25, 0.25 - 0.75 and 0.50 - 9.00. DIM (mg/kg/person) values for Cd, Cu and Zn were found to be in the ranges of, 0.011 - 0.025, 0.003 - 0.009 and 0.006 - 0.103 respectively. Further analysis showed that only Cd had HRI values > 1. On the contrary, all the metals have THQ and TTHQ values < 1. Bacteriological assessment revealed the presence of Bacillus spp., Klebsiella spp., Salmonella spp., and Proteus spp. in the samples in the percentage prevalence of 51.85, 18.52, 18.52 and 11.11 % respectively. Cumulative bacteria prevalence for Wurukum, North-Bank, High-Level and Wadata and Modern Market were thus; 25.93, 22.22, 18.52, and 14.81 % respectively. With Cd values above threshold limit and the prevalence of these pathogenic bacteria species, potential of metal toxicity, typhoid and Diarrhea outbreaks is imminent.

Keywords: Bacteriological Analysis, Cassava flakes, Heavy metals, Human health risk assessment

INTRODUCTION

Cassava (*Manihot esculenta crantz*) is one of the major food sources of the tropics, with diverse common food forms, such as the flakes (Garri), Flour, *akpu*, chips, abacha and fufu amongst others and as such is regarded as "the bread of the tropics" (Nyamekye, 2021; Saravanan *et al.*, 2016). It has aligned greatly with Nigeria's rapid growing population (Ilona *et al.*, 2017). Being the sixth most significant crop plant globally and primary calorie source in tropical places, Nigeria leads its production by 19 % of the global market share (Burns *et al.*, 2010; Nyamekye, 2021). Over 50 million Nigerians depend largely on cassava for about 70 % of the daily calorie need (Ogunleye *et al.*, 2014). The general nutritional profile of cassava is represented thus; carbohydrate (32 - 35 %), protein (2 - 3 %), moisture (75 - 80), fat (0.1 %), fibre (1 %), ash (0.70 - 2 %) (Nkansah *et al.*, 2021). Following the high moisture content of cassava, the presence and fluctuation of cyanide which is harmful to humans, freshly harvested cassava root tubers cannot be stored over a lengthy period as it begins to decompose within days of harvest (Uchechukwu *et al.*, 2015). Cassava must therefore be processed and transformed into other forms to increase the shelf life of the products, ease transportation, and marketing, reduce cyanide content and improve palatability (Simonyan, 2014).

Cassava flakes commonly referred to as garri is a granular, dry, crunchy, creamy white product obtained from cassava, with improved organoleptic properties and ease of handling and storage (Awoyale *et al.*, 2021; Okechalu *et al.*, 2022). Hence, most developed and convenient food forms from cassava (Samuel *et al.*, 2021). Thus, garri has established itself as a genuine national cuisine with market presence in cities with high level preference particularly in urban areas. In Nigeria, garri serves as a daily staple food and is consumed by every stratum of the society; the rich, the poor, and every age group apart from infants within the first three months of birth (Adowei *et al.*, 2020). Garri is gradually becoming an intercontinental dish as many emigrants from Nigeria and Africa, living in United States, Europe and other foreign lands are importing it to their destinations for consumption (Nwibo *et al.,* 2017).

Despite this associated relevance, garri is still typically sold by the roadside, even on busy highways. By this means, garri is exposed to air dust and car exhaust pollutants and as much as disease causing microbes (Dibofori and Edori, 2015). Particularly, the heavy metals pollution load is proportional to the increasing vehicular traffic hence, the growing concern and concentration of these pollutants in garri (Maeaba *et al.,* 2021). The scenario of roadside open space display of garri on sale, aside attracting and accumulating heavy metals as aforementioned, is linked with microorganisms (Omorodion and Chijor, 2020).

It is logical therefore, to understand the unhygienic situation garri is placed in by its open space roadside marketing, which introduces these heavy metal pollutants and possibly microbes into it. Even though, humans and some other organisms essentially need very little of some of these metals such as Cu, Co, Mn, Ni, V, Mo, Fe, and Zn, for proper metabolic functioning such as bone growth (Nieder *et al.,* 2018) and in the cases of Cu and Zn as enzymes activators (Zhang & Zheng, 2020). Their presence in high quantities however, is rather toxic to humans with accompanying neurological and cardiovascular challenges (Chen *et al.,* 2020).
It is worthy to note that some heavy metals such as Cd, Pb, and Hg, even in very minute amounts can be hazardous as they possess no positive metabolic functioning impact on organism. Following heavy metal toxicity, they are persistent, bio-accumulating and bio-magnifying (Ubong *et al.,* 2022); and non-biodegradable in the environment hence, are regarded top priority public health hazard (Ali *et al.,* 2021). Acute or chronic exposure might cause nausea, anorexia, vomiting, gastrointestinal irregularities, and dermatitis, among other symptoms. Each heavy metal genre has its own set of impacts and symptoms in terms of human health (Shikha & Singh, 2021). The presence of significant amount of these metals has diverse harmful effects for example, exposure to lead damages the central nervous system (CNS) and produces neurological impairment due to its capacity to imitate and block the actions of calcium in its neurotransmission function (Marchetti, 2014). Non proper microbial safety post processing handling of garri attracts organisms that are harmful to humans because they produce strong toxins (mycotoxin), which can have negative consequences on health. It established that some of these mycotoxins have cytocidal effects while; others only cause neurological damage (Yassein, 2020). Thus, the presence of these germs in ready-to-eat meals is a great threat to human health.

Human Health Risk Assessment

Prolong exposure to heavy metals can cause accumulation in target tissues such the brain, liver, bones and kidney, leading to magnified harm to the human system. Upon the assumption that these substances may be carcinogenic; human health risk assessment becomes pertinent (Mohammadi *et al.,* 2019). Some of the prominent health risk assessment indices include; daily intake of metal, health risk index target hazard quotients and total target hazard quotients.

Daily intake of metals (DIM)

This is the amount of a substance in food or drinking water that can be consumed daily over a lifetime without presenting an appreciable risk to health. It is usually expressed as milligrams of the substance per kilogram of body weight per day and applies to chemical substances such as food additives, pesticide residues and veterinary drugs. It is estimated using equation 1:

$$DIM = \frac{Cmetal \times Dintakeofgarri}{Baveragebodyweight} \qquad (1)$$

Where: C_{metal} = concentration of heavy metal in the garri sample (mg/kg)
$D_{intake\ of\ garri}$ = daily intake of garri
The Daily Intake of garri = 800 g (0.8 kg) as adopted by Kigigha *et al.* (2018)

Health risk index (HRI)

The health risk index is usually calculated using daily metal intake and the corresponding reference oral dose (Chaoua *et al.,* 2019), as represented in equation 2.

$$HRI = \frac{DIM}{RfD} \qquad (2)$$

DIM = daily metal intake
RfD = reference oral dose; Cadmium 0.001, Copper = 0.04
Nickel = 0.02, Chromium = 0.03, Zinc = 0.3, Lead = 0.004 (USEPA, 2000)
When the health risk index is <1, it poses no health effect but when the ratio is ≥ 1 it indicates that the population will experience health risk.

Target hazard quotients (THQ)

Index for prolong exposure; used to determining lifelong exposure to heavy metals through diet is the target hazard quotient (Zhou *et al.,* 2016). The United States Environmental Protection Agency (EPA) created target hazard quotients to estimate the possible health harm associated with long-term exposure to chemical contaminants (Harmanescu *et al.,* 2011). It can be determined using equation 3:

$$THQ = \frac{EF \times ED \times FIR \times CHM}{RFD \times BaW \times AT} \times 10^{-3} \qquad (3)$$

THQ = Target Hazard Quotient
EF = the exposure frequency; 350 years (USEPA, 2011)

ED = the exposure duration; 30 years (USEPA, 2011)
FIR = Food ingestion rate
CHM = concentration of heavy metal in the garri
RfD = oral reference dose for the heavy metals under study
BaW = body average weight for adult; 70 kg (USEPA, 2011)
AT = average time for non-carcinogen (days); carcinogens = 365 x 70,
Carcinogens = 365 x ED
When the target hazard quotient is < 1, it suggests no potential adverse effects (Shaheen *et al.*, 2016).

Total target hazard quotient (TTHQ)

The total target hazard quotient is the sum of each metal's target hazard quotients (Ezemonye *et al.*, 2019). It is expressed thus:

TTHQ = ∑total hazard quotients of individual heavy metals under study.

Bacteria

Bacteria play vital roles both in productivity and in cycling substances essential to all other life-forms (Ho *et al.*, 2020). Despite the associated relevance, bacteria are known to also cause a wide array of health challenges to man and to other organisms including plants. D. E. Salmon, an American bacteriologist, first identified *Salmonella* in the intestines of pigs in 1884 (Liberia *et al.,* 2022). One of the most prevalent food borne illnesses caused by this bacterium is *salmonellosis* (Vajda *et al.*, 2021). More than 2 billion people worldwide experience diarrheal sickness each year, and the World Health Organization (WHO) estimates that food is the source of infection in one-third of these cases (Popa & Papa, 2021). Alongside the aforementioned bacterium*; Bacillius spp, Klebsiella spp., E. coli*., among others are link with endless list of ailments.

MATERIALS AND METHODS

Study area

Samples were collected from five (5) major markets (North-Bank, High-Level, Wadata, Modern and Wurukum markets) within Makurdi town. Makurdi is the capital of Benue State popularly known as the *"food basket of the nation"* located between latitude 7^0 35'N-7^0 50'N and longitude 8^0 24'E-8^0 38'E. Makurdi is in central Nigeria, and part of the Middle Belt region of central Nigeria created in 1976. The city is situated on the south bank of the Benue River. As reported in 2016, Makurdi and its surrounding areas had an estimated population of 365,000 and a total area of 36 square kilometers with a temperature of 29 degrees Celsius. Makurdi contains the base for the Nigerian Air Force's MiG 21 and SEPECAT Jaguar aircraft squadrons and the Nigerian Army's 72 Special Forces (SF) Battalion.

Sample collection

Samples of white Garri were purchased from different roadside marketers within the five major markets (North-Bank, High-Level, Wadata, Modern and Wurukum markets) in Makurdi. The samples purchased were packaged into sterile Ziploc bags and were correctly labeled for easy identification after which, they were transported to the Research Laboratory and Microbiology Laboratory at the South-core axis of the Joseph Sarwuan Tarka University, Makurdi for heavy metals and bacteria analysis respectively. The presence of the following heavy metals was ascertained, they were; Pb, Cd, Ni, Cr, Cu and Zn.

Sample pre-treatment

The garri samples were dried in an oven at 105 ºC in order to remove moisture, they were pulverized and sieved (100 mm mesh) after which they were transferred into airtight containers.

Sample preparation for heavy metal analysis

The method adopted was described by Ideriah *et al.* (2018). Five samples were randomly selected for the heavy metal analysis. Each of the powdered samples (2 g) was weighed into beakers (50 mL). They were further predigested with 10 mL of 0.1 M nitric acid (15 mL). The entire contents were heated to a temperature of 125 °C for 2 h. The digests were filtered using the what-man filter paper into 50 mL flasks. Two portions of distilled water (5 mL) were used to rinse the beakers and the content filtered into the flasks (50 mL). The filtrates were allowed to cool to room temperature before dilutions were made to the 50 mL mark with distilled water. The prepared samples were transferred into plastic sample containers and taken for the heavy metals analysis using Flame Atomic Absorption Spectrophotometer (FAAS; Varian SpectrAA 600).

Sample preparation for bacteria test

Sterilization of materials

All materials were adequately and appropriately sterilized before and after use. Glass wares such as test tubes, conical flasks, pipettes, etc. were thoroughly washed with detergents, rinsed properly with water and drained. They were wrapped in aluminum foil and sterilized in hot air oven at 170 ºC for 1 h. All media used were prepared according to the manufacturer's instruction. Prepared media were autoclaved at 121 ºC for 15 minutes. The laboratory bench was always swabbed using 70 % alcohol for disinfection before analysis. Every isolation and inoculation were done near the flame in order to reduce contamination of the agar plates tubes.

Bacteria isolation, identification and enumeration

The method of Amare *et al.* (2019) was adopted. Each garri samples (1 g) was weighed and dissolved in 9 mL. The homogenates were further serially diluted by mixing one part of homogenate (1 mL) with nine parts of diluents which is distilled water (9 mL) to have a serial dilution of 10^{-1} using test tubes and then transferred into the culture media which was prepared according to the manufacturer's instruction. After mixing each tube, suspension (1 mL) from each test tube was measured using a syringe and later transferred into the petri dishes, the suspensions were spread using wire loop onto a Nutrient Agar media for Bacteria growth. The Nutrient Agar was treated with Fluconazole and this served as a fungi growth inhibitor. The plates were incubated at 37 °C for 24 h for bacterial growth.

Biochemical test

Distinct isolates were sub-cultured into nutrient agar and incubated to make the sample refresh for different biochemical tests. Colonies were inoculated into the following biochemical tests for identification of Gram negative and gram-positive bacteria: Catalase test, Simmons Citrate, Urea and Sulfide Indole Motility (SIM). The inoculated biochemical tests were incubated at 37 °C for 24 h and checked for any color change; subcultures of the isolates that grew on nutrient agar.

Microscopic test

The slides were first prepared by dropping a full loop of water on them followed by colonies using a well sterilized wire-loop. The slides were further washed with crystal violet solvent, Lugol's iodine, alcohol and safranin (Johnson *et al.,* 2016). At every point of staining, distilled water was used in washing off the stains. This was done repeatedly for the slides prepared for microscopy. They were taken for bacteria identification under the microscope which gave information on the shape, colour and type of gram bacteria present.

Statistical analysis

Statistical Package for Social Sciences (SPSS, Version 20) software was used for the statistical analysis of the bacteriological profile of the samples. A one-way analysis of variance (ANOVA) was carried out for the bacteria count at P = 0.05.

RESULTS AND DISCUSSION

Levels of selected heavy metals in the studied cassava flakes

Selected heavy metals were tested for in the garri sold in makurdi markets and it was found that, cadmium, copper and zinc were present, as shown in Table 1. The quantities of the detected heavy metals followed the trend: Zn > Cd > Cu.

This result also agreed with the works of Dibofori and Edori (2015). Furthermore, as earlier established by Dibofori and Edori (2015), Cadmium which is second in the trend has its concentration exceed the permissible limit of 0.1 mg/kg EU standard. Copper which happens to be least among the three, and an essential metal at low concentrations, was found to fall within the acceptable limit set by CODEX (2011). This was found to be in agreement with the findings of similar works as established by Ogbonna *et al.* (2017). The finding of this study also shows that, the copper content in the flakes was lower than the values reported for cassava flakes sold in major markets in Yenaoga, Bayelsa State as reported by Kigigha *et al.* (2018).

Human health risk assessment of heavy metals in the cassava flakes

From the estimated daily intake of Cd (mg/kg/person) shown in Table 2, the human health risk associated with Cadmium toxicity was more in Modern Market and least in Wadata market. This result correlates with the average vehicular traffic in such market. Modern Market is the biggest market and draws attendance from all part of Makurdi, particularly people of affluence; usually attending the market in their cars and other rides. Even though, no major road(s) traverse the market, unlike the other markets. Furthermore, the pattern seemed to reflect the popularity of these markets. Despite the highest daily intake of Cd metal attained by Modern market, the concentration is still lower than the upper threshold allowable daily intake limit of cadmium (0.064 mg/person/day) as established by USEPA (2013). This result of Cd in the flakes is in agreement with the findings in similar studies reported by Adowei *et al.* (2020); Orisakwe *et al.* (2012).

The observed daily intake of Cu and Zn were in the ranges of 0.003 - 0.009 mg/kg/person and 0.034 - 0.103 mg/kg/person respectively. The highest daily intake values of Cu and Zn were observed in Wurukum and Modern markets respectively. As established by the Institute of Medicine, earlier reported by Kigigha *et al.* (2018), Cu and Zn were found to be below the recommended upper tolerance daily intake limits of 10 mg/day and 40 mg/day respectively.

The observed concentration of Cu and Zn in this study agreed with the findings of the study conducted by Kigigha *et al.* (2018). The observed geometric behaviour of the daily intake of Cd, Cu and Zn amongst the five markets for adult weight was in the trend: GMM > GWUM > GNB > GWM > GHL. Meanwhile, the observed metal trend was Zn > Cd > Cu.

The Health Risk Index (HRI) which is a tool used in predicting possible adverse health effects on population was determined for the various markets using the DIM and reference dose (RFD) values for the metals under case study. HRI values greater than 1.0, implies potential non-carcinogenic effects (Adowei *et al.*, 2020). The HRI for Pb, Cr and Ni were not determined. From the results in Table 3, it can be seen that the HRI values for adult were found to be between 10.000 and 25.000/person for Cd. The high HRI values of Cd indicates that uncontrolled consumption of commercial garri may pose a health problem, given that Cd has no biological function in the human body. Remediation approach is required if the general public should continue the trend of consumption of garri or there is need to reduce the excessive consumption to avoid health catastrophe hence the permissible HRI limit is exceeded. HRI values for Cu and Zn were seen to be within the HRI permissible limit < 1 and the ranges of 0.075 - 0.225/person and 0.325 - 1.00/person respectively, as shown in Table 3. The geometric behaviour of the HRI values of heavy metals (Cd, Cu and Zn) for an adult for the study Areas were: GMM > GHL > GWUM > GNB > GWM. Geometric trend for the HRI values for the heavy metals was Cd > Zn > Cu. The mean HRI computed in Table 3, exceeded 1 which indicates that the combined HRI values of these metals could result into hazard health effects.

Computed THQ values for all the detected metals in the five market areas investigated revealed that THQ is < 1. This indicates no life-long health concern for the exposed population and agreed with Adowei *et al.* (2020) and Kgigiha *et al.* (2018), who also carried out similar studies on garri. The geometric behaviour of the THQ values of heavy metals (Cd, Cu and Zn) amongst the five markets was: GWUM > GMM > GHL > GNB > GWM for an adult. Hence, the metal trend was Cu > Cd > Zn.

The Total Target Health Quotient (TTHQ), which is a summation of the target health quotients of metals, was calculated for adult as shown in Table 4. The obtained values revealed that the TTHQs for the studied areas with respect to metals under study were less than 1 which signifies no potential adverse health effects.

Bacteriological profile of analyzed samples

The Total Viable Count (TVC) of the white garri samples collected from the various sampling areas within Makurdi Metropolis revealed the highest colony count thus: GWM > GWUM > GNB > GMM > GHL, as shown in Table 5. The colony count values indicated that the various garri food products are potentially polluted considering the recommended food safety limits and the use of TVC as indices of measurement of food quality, which is a useful quantitative assay of microbial load and contamination (Ogbonna *et al.*, 2017).

The results of the statistical analysis at P = 0.05 revealed that there were significant differences in the contamination levels of the garri samples. The colony count values of the samples showed that there was statistically significant difference between the contamination levels of samples from Wadata and High Level markets. However, Wadata and the rest of the markets showed no significant difference in their contamination levels. This high contamination levels can be attributed to unclean environment, customer's attitudes and open display pattern. This result also agrees with the findings of Olapade *et al.* (2014). The study further asserts that, unclean environment is one of the major contributors to the microbial contamination of food as well as the practice of leaving garri in the open for sale and customers' attitudes toward the displayed garri could have contributed to the high bacteria load of the samples as they touch the garri with their bare hands to test it out before they buy (Olapade *et al.*, 2014). The bacteria isolated from the samples were *Bacillus* spp., *Klebsiella* spp., *Salmonella* spp., and *Proteus* spp. They were identified through their various cultural, morphological and biochemical characteristics as presented in Table 6. Similarly, Ogbonna *et al.* (2017) and Egbuobi *et al.* (2015) also isolated *Bacillus* spp. from garri. The isolation of bacteria from garri has also been demonstrated in a study carried out by Osho *et al.* (2010), in which bacterial strains: *Actinomyces* sp., *Bacteriodes* sp., *Corynebacterium* sp., *Pseudomonas* sp., *Lactobacillus* and *Le uconostoc* sp., were isolated. The presence of *Bacillus* spp. in the samples may be due to its ability to withstand some processing conditions as reported by Ogugbue *et al.* (2011), aside the tendency of contamination through the marketing strategy. The study further explains that *Bacillus* spp. is a spore former and known to persist even in environmental stress. The presence of *Bacillus* spp. and *Klebsiella* spp. in these samples is an indication of danger, being they pathogenic in nature (Egbuobi *et al.*, 2015; Okafor *et al.*, 2018). Food safety guideline considers most ready-to-eat foods satisfactory if *Salmonella* are not detectable in 25 g of the food (Ogbonna *et al.*, 2017). Thus, the presence and detection of *Salmonella* spp. from a gram of garri implies contamination and great health threat. The prevalence of these bacteria isolates as observed in the garri samples is as shown in Table 7. The high occurrence of bacteria in garri from these markets may be attributed to the poor sanitary condition, storage and marketing strategies (Johnson *et al.*, 2016).

Table 1: Levels of selected Heavy Metals (mg/kg) in Cassava Flakes (Garri) Sold along the roadside in Makurdi Metropolis

Sample ID	Pb	Cd	Cr	Ni	Cu	Zn
GHL	ND	1.75	ND	ND	0.25	3.75
GMM	ND	2.25	ND	ND	0.50	9.00
GNB	ND	1.25	ND	ND	0.25	3.00
GWM	ND	1.00	ND	ND	0.25	0.50
GWUM	ND	1.50	ND	ND	0.75	5.25
GB	ND	ND	ND	ND	ND	ND

GHL = High-Level Garri, GMM = Modern Market Garri, GNB = North-Bank Garri, GWM = Wadata Market Garri, GWUM = Wurukum Market Garri, GB = Blank, ND = Not Detected

Table 2: Daily Intake of Metal (DIM) for detected heavy metals for an adult (mg/person/day)

Sample ID.	Cd	Cu	Zn
GHL	0.020	0.003	0.043
GMM	0.025	0.006	0.103
GNB	0.014	0.003	0.034
GWM	0.011	0.003	0.006
GWUM	0.017	0.009	0.060
Mean	0.017	0.005	0.049

GHL = High-Level Garri, GMM = Modern Market Garri, GNB = North-Bank Garri, GWM = Wadata Market Garri, GWUM = Wurukum Market Garri, GB = Blank, ND = Not Detected

Table 3: Health Risk Index (HRI) and ∑HRI values of selected heavy metals for adult

Sample ID	Cd	Cu	Zn	∑ HRI
GHL	20.000	0.075	0.143	
GMM	25.000	0.150	0.343	
GNB	14.000	0.075	0.113	
GWM	11.000	0.075	0.020	
GWUM	17.000	0.225	0.200	
Mean	17.400	0.120	0.160	17.680

GHL = High-Level Garri, GMM = Modern Market Garri, GNB = North-Bank Garri, GWM = Wadata Market Garri, GWUM = Wurukum Market Garri

Table 4: Target Health Quotients (THQ) and Total Target Hazard Quotients (TTHQ) values of selected heavy metals in adult

Sample ID.	Cd	Cu	Zn	TTHQ
GHL	$1.\ 9 \times 10^{-2}$	7.0×10^{-5}	1.4×10^{-4}	1.9×10^{-2}
GMM	2.5×10^{-2}	1.4×10^{-4}	3.3×10^{-4}	2.5×10^{-2}
GNB	1.4×10^{-2}	7.0×10^{-5}	1.1×10^{-4}	1.4×10^{-2}
GWM	1.1×10^{-2}	7.0×10^{-5}	2.0×10^{-5}	1.1×10^{-2}
GWUM	1.6×10^{-2}	2.1×10^{-1}	1.9×10^{-4}	2.2×10^{-1}

GHL = High-Level Garri, GMM = Modern Market Garri, GNB = North-Bank Garri, GWM = Wadata Market Garri, GWUM = Wurukum Market Garri, GB = Blank, ND = Not Detected

Table 5: Mean Total Viable Count (TVC) of Garri Samples from Various Markets in Makurdi Metropolis

Sample Location	TVC (M±SD)
GWUM	35.33±3.06[ab]
GHL	21.00±4.00[b]
GMM	27.67±9.61[ab]
GWM	37.00±10.58[a]
GNB	30.67±8.50[ab]
P-value	0.165

P< 0.05 TVC (total viable colonies), M = Mean, S.D = Standard deviation. Note: means on the same row with different superscript differ significantly. GHL = High-Level Garri, GMM = Modern Market Garri, GNB = North-Bank Garri, GWM = Wadata Market Garri, GWUM = Wurukum Market Garri

Table 6: Cultural, Morphological and Biochemical characteristics of Bacteria Isolates

CC	CS	MP	GR	CAT	CIT	URE	IND	H_2S	MOT	Bacteria
Mucoid pink	**Circular**	**Rod**	-	+	+	+	-	-	-	*Klebsiella*
Pale	**Circular**	**Rod**	-	+	+	+	+	-	+	*Proteus*
White	**Irregular**	**Rod**	+	+	+	-	-	-	-	*Bacillus*
Pale	**Circular**	**Rod**	-	+	+	-	-	-	+	*Salmonella*

CC (colony color), CS (colony shape), MP (Morphology), GR (gram reaction), CAT (catalase), CIT (citrate), URE (urease), IND (indole), H_2S (hydrogen sulphide), MOT (motility), + (positive), - (negative)

Table 7: Percentage Prevalence of Bacteria Isolates across Study Locations

Sample Area	*Klebsiella*	*Proteus*	*Bacillus*	*Salmonella*	Total
GWUM	1(3.70)	0(0.00)	5(18.52)	1(3.70)	7(25.93)
GHL	2(7.41)	0(0.00)	2(7.41)	1(3.70)	5(18.52)
GMM	2(7.41)	1(3.70)	0(0.00)	1(3.70)	4(14.81)
GNB	0(0.00)	2(7.41)	3(11.11)	0(0.00)	5(18.52)
GWM	0(0.00)	0(0.00)	4(14.81)	2(7.41)	6(22.22)
Total	5(18.52)	3(11.11)	14(51.85)	5(18.52)	27(100.00)

CONCLUSION AND RECOMMENDATION

This study has established the presence of heavy metals and pathogenic bacteria in the samples. The research also revealed the concentrations of these metals to be within the tolerable limits except cadmium. However, the summation of HRI value and the bacteriological profile of these samples imply that the food product is unsafe for consumption, particularly for long term. Even though the THQ values on the other hand were within the permissible limit, indicating no life-long health concern for the exposed population, the presence of the bacteria species isolated from the samples which are pathogenic in nature, says otherwise. Therefore, the potential outbreak of illnesses such as typhoid fever and diarrhoea is likely. It is pertinent therefore, to educate producers, sellers and buyers on the need for proper handling of this popular food in the face of our polluted environment. The consumption of contaminated garri therefore portends a potential risk to consumers based on the findings of this research.

Declaration of conflict of interest

The authors declare no conflict of interest.

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