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Research Article

Estimation of the Composition and Chemometric Characterisation of Trace Metals in Selected Cereal Foods from Minna, Niger State, Nigeria

[*1]Umar, A., [1]Yerima, H., [1]Baba, H., [1]Musa, Y., [2]Abdullahi, I.B., [2]Zhitsu, U.N., and [3]Makun, D.M.
[1]Department of Chemistry, Niger State College of Education, Minna, Nigeria
[2]Department of Physics, Niger State College of Education, Minna, Nigeria
[3]Department of Computer Science, Niger State College of Education, Minna, Nigeria
[*]Correspondence email: yabagi7up@gmail.com

Abstract

Balanced food consumption is one of the most important determinants of human health. Trace elements are a class of micronutrients that are needed for biochemical and physiological activities in very small quantities (less than 100 mg/day). They could, however, be deleterious to human health when present at either excessive or deficient concentrations within the body. The concentrations of five trace metals (Zn, Cu, Fe, Mn, Cr) in seven commonly consumed cereal grains from four major markets in Minna metropolis, Niger state, Nigeria were examined in this study. A total of 28 composite samples were made from 140 purchased cereal samples and analysed using an Atomic Absorption Spectrometer (AAS) after wet acid digestion with Aqua Regia acid mixture. The result showed a wide variation in trace metal concentrations, with Cr not being detected in 6 of the samples. Fe (66.96±48.52 mg/kg) had the highest overall mean concentration, while Cr (1.14±2.12 mg/kg) had the lowest, with the overall individual mean metal concentrations in the order: Fe > Zn > Mn > Cu > Cr. The levels (mg/kg) of Zn, Cu, Fe, Mn, and Cr in the seven cereal foods ranged 2.18–25.03, 1.30–5.18, 12.53–207.25, 1.58–38.33, and ND–9.95, respectively. Recovery values were within the range of 95–110%. Positive correlations were observed between Zn/Cu (0.797), Fe/Cr (0.671), Cu/Mn (0.659) and Zn/Mn (0.538). The Principal component analysis (PCA) Biplot analysis identified useful cereal foods for managing mineral deficiency diseases. Hierarchical cluster analysis (HCA) revealed closely substitutable pairs of cereals based on their trace metal contents. Except for only 4 of the analysed samples that had Cr with values above recommended standards, all the other studied metals in the 28 composite cereals had concentration values below the acceptable limits of FAO/WHO in foods, suggesting their relative safety for the consumption. These findings provide valuable insights for policymakers and stakeholders in Nigeria's food safety and public health. Adequate periodic monitoring and *implementation of necessary measures to regulate and curb excessive intake of trace metals by consumers is recommended. Such periodic studies should incorporate more foodstuffs, more food groups, and more trace / major elements to promptly ascertain their wholesomeness and safety for consumers.*

Keywords: Trace metals, Cereal grains, Chemometrics, Food safety, Mineral deficiency, AAS.

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Introduction

Cereal grains are the most important dietary energy source around the world, containing also a variety of dietary fibres, minerals, and vitamins (Yang *et al.,* 2020; Poutanen *et al.,* 2014). They contain carbohydrates and proteins, and protect against chronic diseases such as colon cancers, type 2 diabetes, and cardiovascular disease (Taylor *et al.,* 2022; Reynolds *et al.,* 2019; Poutanen *et al.,* 2014). Hence, they are useful for healthy diet and proper functioning of the body (Rubio-Armendáriz *et al.,* 2022; Kulkarni, 2017; Kiri *et al.,* 2016). Rice, maize, sorghum, millet, wheat and acha (fonio) are important cereal grains grown and consumed in Nigeria and around the world (Ikem *et. al.,* 2023; Nyachoti *et al.,* 2021), with a global and Nigeria cereal production of 296 billion tons and 26.2 million tons, respectively as at 2018 (Ikem *et. al.,* 2023; The World Bank Group, 2023: https://data.worldbank.org/indicator/). Cereal grains may uptake toxic metals along with essential elements and nutrients (both macro and micro) from natural soils, fertilizer/manure as well as herbicides/pesticides applications, irrigation water, and atmospheric dust (containing industrial and vehicular emissions); also, the grains may get contaminated through indiscriminate waste disposal, leachates from landfills, industrial effluents, and mining activities; or during storage and processing (Ikem *et al.,* 2023; Rom´an-Ochoa *et al.,* 2021; Khaneghah *et al.,* 2020; Pedron *et al.,* 2021; Afonne and Ifediba, 2020; Compaore *et al.,* 2019).

Food consumption is the major path for human exposure to certain environmental contaminants, including heavy metals and excess trace elements (Umar *et al.,* 2023; Akinyele and Shokunbi, 2015a). Trace elements are micronutrients that are needed by humans in very small quantities (Akinyele and Shokunbi, 2015a; Fraga, 2005). Trace elements are vital body components in our foods which form essential parts of enzymes and molecules that provide optimal nutrition and health, and play important roles in maintaining several physiological and biochemical processes (Joseph *et al.,* 2016; Ole, 2012). Chromium is vital for the metabolism of lipids, carbohydrates, and protein, as well as insulin activity. Copper is vital for both physical and mental development such as connective tissue, nerve coverings, and bone; iron and energy metabolism in cells; and is required for women's fertility. Iron is a vital in haemoglobin for transportation of oxygen to body tissues; and takes part in redox activities within the body. Manganese is essential for bone formation and development, and in metabolism of carbohydrate, amino acid, and lipid; also in regulation of blood sugar, and absorption of calcium. While Zinc is vital for over seventy processes, structures or enzyme activities like carbohydrate, lipid and protein synthesis / degradation; and in the regulation of gene expression and intracellular signaling. (Sarker *et al.,* 2023; Arigbede *et al.,* 2019; Falah and Saja, 2017; Joseph *et al.,* 2016; Bowman *et al.,* 2011; FSANZ, 2011).

Although trace elements play major roles in biochemical and physiological functions and reactions in the human body, they could however be toxic and deleterious to health when present at excessive concentrations within the body (Al-khamaiseh *et al*., 2025; Magaji *et al.,* 2023; Adam *et al.,* 2022; Filipiak-Szok *et al.,* 2015). Hence, the need for consumption safe limits and continuous monitoring. Data on trace element composition in foods are of utmost importance to consumers, educationists, and health professionals. Their measurement (in foods and the body) is increasingly attracting interest from researchers and physicians to ensure food safety, as deviations in their uptake and/or metabolism are related to certain dysfunctions (Umar *et al.,* 2023; Awad and Lilly, 2010). Food safety and health are therefore important issues for governments, producers, and consumers (Amarloei *et al.,* 2025; Kholil *et al.,* 2019). Food safety implies the absence of harmful substances in food for the consumer's health or its presence at an acceptable level (Taghavi *et al.,* 2024; Akhtar, 2015)

There is limited data on the elemental contents of cereal grains and intake estimates for the Nigerian population. Some recent studies on food safety and public health in Nigerian cereals foods are more focused on Southern parts with little on those from the Northern parts of the country, especially on estimating their daily intakes and hazard quotients (Micah *et al.,* 2024; Shokumbi *et al.,* 2023; Ikem *et al.,* 2023; Obasi *et al.,* 2022; Orosun, 2021; Nnaji *et al.,* 2020; Shokunbi *et al.,* 2019; Tirima *et al*., 2018; Emurotu and Onianwa, 2017; Akinyele and Shokunbi, 2015a; Orisakwe *et al*., 2015; Babatunde and Emeka-Oha, 2015). Research works on the estimation of dietary intake on Nigeria foods (especially North-central Nigeria) are quite few and insufficient from available literature. Hence, this work attempted to fill such knowledge gap on cereal foods from Minna, Niger State in North-central Nigeria. It aims at generating relevant data on the concentrations of five trace metals (Zn, Cu, Fe, Mn, Cr) in seven cereal grains consumed in Minna, Niger State, Nigeria. The research has the following specific objectives: (i) to determine the concentrations of the trace elements in the sampled grains to ascertain safety for human consumption and add to nutritional data, (ii) to carry out the correlation analysis between the trace elements in the sampled foods, (iii) to apply Chemometrics using the Principal Component and Hierarchical Cluster analysis on the generated trace element data for latent information or features.

Materials and Method

Study Area and Sample Collection

Nigeria, the most populous Black Nation in the world, is situated between latitudes 4° and 14°N and longitude 2° and 15°E on the Gulf of Guinea, West of the African continent comprises 36 states and the Federal Capital Territory, Abuja. Niger State is one of the 6 states in the North-Central zone of the country. It lies on 3.20° E and longitude 11.30° N covering a total land area of 76,363 km^2 (29,484 sq mi), and has an estimated population of about 3,954,772 as at 2006. It has twenty-five (25) Local Government Areas, with the capital at Minna. Farming is the dominant occupation of the state, but it also has natural mineral resources that favour mining activities.

The cereal food samples were acquired by market-basket survey (Akinyele and Shokunbi, 2015a), which is based on general guidelines provided by the World Health Organisation (WHO, 1985) in which composite samples (for analyses) were made by mixing equal quantities of five dried varieties of each of the cereal samples purchased from local markets. Thus, the cereal samples were purchased from major markets in Minna. Five varieties of the seven most commonly consumed cereals were collected to form a food basket from each market. Each food item was purchased by systematic random sampling and carefully packed in well labelled polyethylene bags and safely transported to the laboratory. In all, a total of 140 cereal food samples were purchased for this research, from which 28 composite samples were made and used for the analysis of the 5 trace elements (Zn, Cu, Fe, Mn, and Cr). The English/botanical names and pictures of the sampled cereals (maize, sorghum, rice, millet, wheat, and acha) are shown in Table 1 and Fig. 1.

Sample Pretreatment

The samples were carefully cleaned to remove sand and other physical impurities. The cereals were oven-dried at 80 – 105 ^{o}C until constant weights were achieved. Equal quantities of five dried varieties of each sample were then mixed to form a composite of the sample. The composite samples were then pulverised with a mill and the resulting fine powder stored in well-labelled, clean, dry and air-tight polyethylene containers ready for digestion (Akinyele and Shokunbi, 2015a; Ihedioha and Okoye, 2013). The mill was washed with distilled water and air-dried each time a fresh sample was ground to avoid contamination of subsequent samples.

Table 1: Common and Scientific Names of Selected Food Samples

S/No	Common Name	Local Name (Hausa)	Scientific/Botanical Name
1	Local Rice	Shinkafar Gida	*Oryza sativa*
2	Foreign Rice	Shinkafar Waje	*Oryza sativa*
3	Maize	Masara	*Zea mays*
4	Guinea Corn	Dawa	*Sorghum bicolor*
5	Millet	Dauro / Gero	*Pennisetum americanum*
6	Wheat	Alkama	*Triticum aestivum*
7	Fonio (Acha)	Acha	*Digitaria exilis*

Figure 1: Common and Scientific Names, & Pictures of Sampled Cereal Foods

Reagents and Solutions

Analytical-grade chemicals were used for this study. Trioxonitrate (V) acid (HNO_3) and Hydrochloric acid (HCl) used were Analar grade from BDH Chemicals, England. Distilled and distilled-deionised water were used to rinse glassware, prepare dilutions, calibrate standard solutions, and bring digests to volume. Fast Sequential Atomic

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Absorption Spectrometer (AAS) Model PerkinElmer PinAAcle 900H was used for the instrumental determination, while OHAUS Explorer Analytical Weighing Balance (EX225D/AD model) manufactured by Ohaus Laboratory Equipment, USA was used for all measurements.

Sample Digestion

The pulverized composite cereal samples were wet digested with freshly prepared Aqua regia mixture. The mixture was prepared by freshly mixing concentrated nitric acid and concentrated hydrochloric acid in a volume ratio of 1:3. Exactly 1.00 g of each of the pulverized sample was weighed into 125 cm^3 Erlenmeyer flask and 20.0 cm^3 of the Aqua regia was added to it in a fume hood. The mixture was tightly covered with a glass slit (to enable refluxing) and heated on a hot plate to 200 ^oC for about 2½ h (until when clear yellow solution was obtained). The digest was allowed to cool and filtered into a 25.0 cm^3 volumetric flask, using Whatman® filter paper No. 42. The conical flask was then carefully rinsed with distilled deionized water, filtered into the content in the volumetric flask and made up to mark with distilled deionized water. This was then transferred to a well cleaned and labeled polystyrene sample bottle and kept for trace metal analyses (Akinyele and Shokunbi, 2015b).

Elemental Analyses using Atomic Absorption Spectrometer (AAS)

The concentrations of the trace metals (Zn, Cu, Fe, Mn, and Cr) in the cereal food samples were determined by a Fast Sequential Atomic Absorption Spectrometer (AAS) Model PerkinElmer PinAAcle 900H at Central Research Laboratory, Bayero University, Kano, Nigeria. The working conditions of the AAS used for analysing the food samples are presented in Table 2:

Table 2: Working Conditions of the AAS Used for the Cereal Food Samples Analyses

METAL	WAVELENGTH (nm)	LAMP CURRENT. (mA)
Zn	213.86	15
Cu	324.75	15
Fe	248.33	30
Mn	279.48	20
Cr	357.87	25
Burner Height = 5-7 mm		
Nebulizer Flow = 1.5 L/min		
Sample Uptake Rate = 3 mL/min		

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Quality Assurance

Standard routine laboratory procedures were adequately adhered to. All apparatus (plastic and glass wares) were thoroughly washed with detergent and soaked in 10 % (v/v) HNO_3 for at least 24 h and then thoroughly rinsed with distilled deionised water before use. All reagents used were of analytical grade, and all solutions were prepared using distilled, deionised water.

Ten percent (10 %) sample blanks and sample duplicates were included in each digestion batch and analysed together with the foodstuff samples for method validation (i.e. to ensure the precision and repeatability of the digestion procedure and the instrumental analyses). The sample blanks were prepared by taking a known volume of the digestion acid mixture through the same digestion procedure and analysed for all the metals (Akinyele and Shokunbi, 2015a).

Spiking with a recovery study was carried out to validate the analytical procedures. Some samples (Beans, Groundnut, Bambara nut) were spiked with standard solutions of the target analyte metals (Zn, Cu, Mn, Cr). From the stock reagents, 0.50 mg/L of Zn, 6.0 mg/L of Cu, 3.0 mg/L of Mn and 6.0 mg/L of Cr solutions were prepared and added to 1.0 g of the samples. The spiked and non-spiked samples were digested and analysed in similar conditions and procedures using the same AAS. The percentage recoveries were calculated as expressed in equation (1) (Asegbeloyin *et al.,* 2015; Ajai *et al.,* 2014):

$$\% \text{ Recovery} = \frac{X-Y}{Z} \; x \;\; 100 \qquad (1)$$

where X = concentration of the spiked sample,
Y = concentration of the un-spiked sample,
Z = concentration of the metal ion added.

The recovery experiment result for the trace metals is presented in Table 3.

Trace Metal Concentrations in Cereals and Comparison with Safe Limits

The trace metal concentrations in the seven cereal grains were compared with the FAO/WHO limits in foods (FAO/WHO, 2022).

Statistical Analyses, Correlation and Chemometrics

Statistical Package for Social Sciences (SPSS -23 Version) was used for descriptive statistics and correlation analysis. PCA and HCA were done using the Solo Workspace Browser, a versatile Statistical Chemometrics software to further analyse the results obtained in this study to extract or reveal some latent features. The **Pearson's correlation** analysis was used to measure the statistical relationship, association, or interdependence between the variables (trace metals) in the studied cereal samples.

Results and Discussion

The recovery experiment result for the trace metals is presented in Table 3. It shows the percentage recoveries that ranged between 93.0 and 104.5 %. They were within the acceptable range (100±10%), thus verifying the validity of the analysis method.

Tables 4 and 5 show the trace metal levels and the descriptive statistics (range and mean±SD) for the trace metal contents in the studied cereals from the four main markets in Minna metropolis. While Tables 6 shows the correlation matrix among the 28 composite cereal food samples.

Table 3: Results of the Recovery Experiments for the Spiked Samples

SAMPLES		Zn	Cu	Mn	Cr
Rice	Unspiked sample concentration (mg/kg)	12.31	3.38	7.06	0.29
	Amount added (mg/L)	2.00	4.00	3.00	1.00
	Spiked sample concentration (mg/kg)	14.20	7.36	9.98	1.30
	Amount recovered (mg/L)	2.09	3.98	2.92	1.01
	% Recovery	104.5	99.5	97.3	101.0
Maize	Unspiked sample concentration (mg/kg)	11.67	1.63	4.08	0.05
	Amount added (mg/L)	2.00	4.00	3.00	1.00
	Spiked sample concentration (mg/kg)	13.60	5.65	7.04	0.98
	Amount recovered (mg/L)	1.93	4.02	2.96	0.93
	% Recovery	96.5	100.5	98.7	93.0
Millet	Unspiked sample concentration (mg/kg)	19.53	3.81	9.68	0.67
	Amount added (mg/L)	2.00	4.00	3.00	1.00
	Spiked sample concentration (mg/kg)	21.51	7.61	12.70	1.61
	Amount recovered (mg/L)	1.98	3.80	3.02	0.94
	% Recovery	99.0	95.0	100.7	94.0

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Table 4: Concentrations (mg/kg) of Trace Metals in the Studied Cereal Food Samples from the Four Main Markets in Minna Metropolis

MARKET	FOOD SAMPLES	Zn	Cu	Fe	Mn	Cr
Kure	Maize	10.98	1.45	22.23	8.75	0.10
	Sorghum	9.98	3.35	33.58	23.60	ND
	Local Rice	7.10	2.78	24.48	11.20	0.28
	Foreign Rice	2.18	1.60	90.68	6.80	0.20
	Millet	23.80	4.25	73.30	14.38	0.55
	Wheat	23.13	3.85	84.48	36.23	4.98
	Acha	18.28	3.03	99.35	18.70	0.93
Gwari	Maize	8.38	1.40	44.40	5.10	0.15
	Sorghum	15.73	2.83	91.35	11.00	4.15
	Local Rice	8.95	2.93	68.13	8.85	0.38
	Foreign Rice	10.33	1.58	21.70	2.88	0.35
	Millet	15.78	3.58	49.05	8.95	0.88
	Wheat	16.15	3.85	54.03	27.95	ND
	Acha	18.75	3.18	95.48	3.95	1.35
Chanchaga	Maize	14.45	1.70	31.55	3.75	ND
	Sorghum	18.23	2.80	76.78	11.55	0.28
	Local Rice	20.23	3.85	40.78	6.40	0.30
	Foreign Rice	3.40	1.30	12.53	1.58	ND
	Millet	18.75	3.88	48.43	8.80	0.13
	Wheat	22.23	4.53	53.85	38.33	0.18
	Acha	17.30	3.55	132.20	6.40	2.53
Bosso	Maize	12.18	1.80	21.03	3.40	ND
	Sorghum	18.55	3.18	207.25	11.80	1.95
	Local Rice	7.75	3.35	24.80	5.93	0.20
	Foreign Rice	4.15	1.33	15.43	2.58	ND
	Millet	24.05	3.98	59.65	11.30	1.00
	Wheat	25.03	5.18	112.60	30.45	1.20
	Acha	14.45	3.03	185.68	3.95	9.95

Tabulated values are means of 3 determinations   ND = Not detected

Table 5: Range and Mean Values (mg/kg) for Trace Metal Content of Cereals from Minna Metropolis

FOOD SAMPLE	N		Zn	Cu	Fe	Mn	Cr
Maize	4	Range	8.38 – 14.45	1.40 – 1.80	21.03 – 44.40	3.40 – 8.75	ND – 0.15
		Mean±SD	11.50 ± 2.53	1.59 ±0.19	29.80 ± 10.81	5.25 ± 2.45	0.06 ± 0.08
Sorghum	4	Range	9.98 – 18.55	2.80 – 3.35	33.58 –207.25	11.00 – 23.60	ND – 4.15
		Mean±SD	15.62 ± 3.97	3.04 ±0.27	102.24 ±74.18	14.49 ± 6.08	1.60 ± 1.91
Local Rice	4	Range	7.10 – 20.23	2.78 – 3.85	24.48 – 68.13	5.93 – 11.20	0.20 – 0.38
		Mean±SD	11.01±6.20	3.23 ±0.48	39.55 ± 20.52	8.10 ± 2.43	0.29 ± 0.07
Foreign Rice	4	Range	2.18 – 10.33	1.30 – 1.60	12.53 – 90.68	1.58 – 6.80	ND – 0.35
		Mean±SD	5.02 ± 3.64	1.45 ±0.16	35.09 ± 37.26	3.46 ± 2.29	0.14 ± 0.17
Millet	4	Range	15.78 – 24.05	3.58 – 4.25	48.43 – 73.30	8.80 – 14.38	0.13 – 1.00
		Mean±SD	20.60 ± 4.03	3.92 ±0.28	57.61 ± 11.66	10.86 ± 2.61	0.64 ± 0.39
Wheat	4	Range	16.15 – 25.03	3.85 – 5.18	53.85 –112.60	27.95 – 38.33	ND – 4.98
		Mean±SD	21.64 ± 3.84	4.35 ±0.64	76.24 ± 28.19	33.24 ± 4.85	1.59 ± 2.32
Acha	4	Range	14.45 – 18.75	3.03 – 3.55	95.48 –185.68	3.95 – 18.70	0.93 – 9.95
		Mean±SD	17.20 ± 1.93	3.20 ±0.25	128.18 ±41.72	8.25 ± 7.06	3.69 ± 4.23
All Cereals	28	Range	2.18 – 25.03	1.30 – 5.18	12.53 –207.25	1.58 – 38.33	ND – 9.95
		Mean±SD	14.65 ± 6.54	2.97 ±1.08	66.96 ± 48.52	11.95 ± 10.24	1.14 ± 2.12

N = number of composite samples ND = not detected SD = standard deviation

Table 6: Correlation Matrix of the Trace Metals Content among the Cereal Food Samples

	Zn	Cu	Fe	Mn	Cr
Zn	1.000				
Cu	0.797	1.000			
Fe	0.406	0.353	1.000		
Mn	0.538	0.659	0.137	1.000	
Cr	0.238	0.179	0.671	0.057	1.000

Trace Metal Contents

The result of the trace metal concentrations in the analysed composite cereals from the four major markets in Minna metropolis, Niger State (Tables 4 and 5) showed a wide variation in levels of the studied trace metals with Cr not being detected in 6 of the 28 cereal samples. For all the 28 examined cereal samples, Fe (66.96±48.52 mg/kg) had the maximum mean concentration, while Cr had the lowest mean concentration (1.14±2.12 mg/kg), and the overall individual mean metal concentrations were in the order: Fe > Zn > Mn > Cu > Cr.

Zn Concentration in the Studied Cereal Samples
Zinc, an essential trace element is a component of many enzymes that is involved in the metabolism of carbohydrates, proteins, and lipids; and is important for growth, development and general wellbeing. Its deficiency leads to coronary heart diseases and various metabolic disorders (Falah and Saja, 2017; Saraf and Samant, 2013). The overall Zn concentration in the studied cereals ranged between 2.18 mg/kg in foreign rice and 25.03 mg/kg in wheat. The highest mean concentration of Zn (21.64±3.84 mg/kg) in the studied cereals was found in wheat, while the lowest (5.02 ± 3.64 mg/kg) was in foreign rice. The mean Zn concentrations in the studied cereals are in the order: Wheat > Millet > Acha > Sorghum > Maize > Local Rice > Foreign Rice.

Maize had a mean Zn concentration of 11.50±2.53 mg/kg. This was higher than the 9.99±3.91 mg/kg mean Zn value recorded for Maize from Cape Verde (Rubio-Armendáriz *et al.*, 2022); but lower than the 18.9±0.8 mg/kg recorded in maize from Jos, Nigeria (Ikem *et al.,* 2023). Sorghum had a mean Zn concentration of 15.62±3.97 mg/kg, which was lower than the 20.2±1.0 and 24.0±3.7 mg/kg mean Zn respectively recorded for white and red sorghum from Jos, Nigeria (Ikem *et al.,* 2023); but higher than the 3.366±0.510 and 7.039±0.047 mg/kg respectively obtained in Shashau and Munga villages of Hong Local Government Area, Adamawa State, Nigeria (Micah *et al.,* 2024). Millet had a mean Zn concentration of 20.60±4.03 mg/kg, which was higher than the 18.8±0.9 mg/kg mean Zn obtained in Finger Millet, but lower than the 32.0±1.1 mg/kg mean Zn obtained in Pearl Millet both an earlier study from Jos, Nigeria by Ikem *et al.* (2023).

The mean concentrations of Zn in local and foreign rice were 11.01±6.20 and 5.02 ± 3.64 mg/kg respectively. These are lower than the 12.5±11.2 and 14.24±1.89 mg/kg mean Zn values recorded for Cape Verde and Beijing, China rice respectively (Rubio-Armendáriz *et al.*, 2022; Wei and Cen, 2020). However, the Zn concentration ranges in both the local and foreign rice recorded in this study are higher than the 2.739±1.218 and 4.879±0.036 mg/kg respectively obtained for Shashau and Waja villages of Hong Local Government Area, Adamawa State, Nigeria (Micah *et al.,* 2024).

The 21.64±3.84 mg/kg mean Zn concentration obtained for wheat in this study was lower than the 26.1±6.3 mg/kg mean Zn recorded in wheat from Jos, Nigeria (Ikem *et al.,* 2023), but higher than the 5.44±1.21 mg/kg mean Zn recorded in in wheat in Beijing, China (Wei and Cen, 2020). Acha (Fonio) had a mean Zn concentration of 17.20±1.93 mg/kg, which was lower than the 32.0±5.0 mg/kg mean Zn value recorded for white Fonio

(Acha) in Mali (Koreissi-Dembélé *et al.*, 2013) and 23.00±3.00 mg/kg recorded in Acha from Plateau State in north-central Nigeria (Glew *et al.*, 2013). Generally, all the 28 analysed composite cereals from the four major markets in Minna metropolis in this study, representing 100 %, had Zn contents that are lower than the acceptable 99.40 mg/kg Zn limits of FAO/WHO in foods (FAO/WHO, 2022).

Cu Concentration in the Studied Cereal Samples

Copper is an essential trace metal that is vital for both physical and mental development in humans. It is necessary for the growth and formation of bone, and the formation of myelin sheaths in the nervous systems, which helps in the incorporation of Fe in haemoglobin and assists in its absorption from the gastrointestinal tract, and its transfer from tissues to the plasma (Falah and Saja,2017; Joseph *et al.,* 2016). The overall Cu concentration in the studied cereals ranged between 1.30 mg/kg in foreign rice and 5.18 mg/kg in wheat. The highest mean concentration of Cu in the studied cereals was found in wheat (4.35±0.64 mg/kg), while the lowest was in foreign rice (1.45±0.16 mg/kg). The mean Cu concentrations in the studied cereals are in the order: Wheat > Millet > Local Rice > Acha > Sorghum > Maize > Foreign Rice.

Maize and foreign rice had comparable mean Cu concentration of 1.59±0.19 and 1.45±0.16 mg/kg respectively, which were lower than the 2.08±0.52 mg/kg mean Cu recorded in maize from Jos, Nigeria (Ikem *et al.,* 2023). They were also lower than the 2.39±0.17 and 2.25±0.28 mg/kg mean Cu values respectively recorded for yellow and white maize in Abeokuta, South-West Nigeria (Akinyele and Shokunbi, 2015a); but were comparable to the 1.50±0.10 mg/kg mean Cu value recorded for Maize in Poland (Grembecka and Szefer, 2022) and 1.58 mg/kg recorded in Thailand rice (Al-khamaiseh *et al.,* 2025).

Similarly, Sorghum, Local rice, Acha, and Millet recorded almost the same Cu mean concentration of 3.04±0.27, 3.23±0.48, 3.20±0.25, and 3.92±0.28 mg/kg respectively; these were higher than the 1.70 and 2.40 mg/kg mean Cu obtained in different Indian sorghums by Shobha and Kalshetty (2017) and Kulkarni (2017); but lower than the 24.12 and 15.95 obtained in Indian rice (Shetty *et al.,* 2025). They were also lower than the 4.88±0.64 mg/kg Cu value recorded for Acha from Plateau State in north-central Nigeria (Glew *et al.*, 2013), and 4.37±0.54 & 6.22±0.42 respectively obtained in Pearl & Finger Millet from Jos, Nigeria (Ikem *et al.,* 2023),

Wheat had a mean Cu concentration of 4.35±0.64 mg/kg. This was higher than the 3.64±0.23 mg/kg mean Cu earlier obtained by Akinyele and Shokunbi (2015a) in wheat from Abeokuta, South-West Nigeria, and 2.96±2.98 mg/kg mean Cu recorded in wheat

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from Cape Verde (Rubio-Armendáriz *et al*., 2022); but was comparable to the 4.85±0.57 obtained for wheat in a recent study from Jos, Nigeria (Ikem *et al.,* 2023). Generally, all the 28 analysed composite cereals in this study, representing 100 %, had Cu contents that were below the acceptable 73.30 mg/kg Cu limits of FAO/WHO in foods (FAO/WHO, 2022).

Fe Concentration in the Studied Cereal Samples

Iron is an essential element that is a vital component of several proteins, including the haem proteins (haemoglobin, myoglobin, and cytochromes) and several enzymes in the body. It plays a vital role in the formation of red blood cells (haemoglobin), oxygen and electron transport in the human body, and in respiration, energy metabolism, destruction of hydrogen peroxide, and DNA synthesis (Umar *et al.,* 2023; Vasudevan *et al*., 2019; Kalagbor and Diri, 2014; FSANZ, 2011; Melaku, 2009). The overall Fe concentration in the studied cereals ranged between 12.53 mg/kg in foreign rice and 207.25 mg/kg in Sorghum. The highest mean concentration of Fe in the analysed composite cereals was found in Acha (128.18±41.72 mg/kg), while the lowest was in maize (29.80±10.81 mg/kg). The mean Fe concentrations in the studied composite cereals are in the order: Acha > Sorghum > Wheat > Millet > Local Rice > Foreign Rice > Maize.

Maize had a mean Fe concentration of 29.80±10.81 mg/kg. This was higher than the 21.0±3.1 mg/kg mean Fe value recorded for yellow Maize from Jos, Nigeria (Ikem *et al*., 2023). It was also higher than the 19.90±1.30 mg/kg mean Fe value recorded for Maize in Poland (Grembecka and Szefer, 2022) and 17.92±0.38 mg/kg recorded in white maize from Abeokuta, South-West Nigeria (Akinyele and Shokunbi, 2015a). Sorghum had a mean Fe concentration of 102.24±74.18 mg/kg, which was also remarkably higher than the 36.45±0.06 mg/kg mean Fe obtained in Ethiopian sorghum (Tegegne, 2015) and 25.90 mg/kg Fe obtained in Indian sorghum (Shobha and Kalshetty, 2017). It was also much higher than the 53.1±17 and 33.8±2.0 mg/kg mean Fe, respectively obtained for white and red sorghum from Jos, Nigeria (Ikem *et al.,* 2023). The obtained mean concentrations of Fe in local and foreign rice in this study were 39.55±20.52 and 35.09±37.26 mg/kg respectively. These are higher than the 7.67±0.76 mg/kg mean Fe value recorded for rice from Abeokuta, South-West Nigeria (Akinyele and Shokunbi, 2015a), but lower than the 84.1±2.15 mg/kg mean Fe values in rice from the Kingdom of Saudi Arabia (Ali and Al-Qahtani, 2012).

Millet had a mean Fe concentration of 57.61±11.66 mg/kg, which was higher than the 40.0±5.8 mg/kg mean Fe obtained in Pearl millet from Jos, Nigeria (Ikem *et al.,* 2023), but lower than the 75.20 mg/kg obtained in Libyan millet (Shaban and Mokhtar, 2016). The

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76.24±28.19 mg/kg mean Fe concentration recorded for wheat in this study was also higher than the 30.75±0.75 mg/kg mean Fe recorded earlier by Akinyele and Shokunbi (2015a) in wheat from Abeokuta, South-West Nigeria, and 48.1±1.5 mg/kg recorded for wheat from Jos, Nigeria (Ikem *et al.,* 2023); but lower than the 128.8±3.41 mg/kg mean Fe recorded in Saudi Arabian wheat (Ali and Al-Qahtani, 2012). The mean Fe concentration of 128.18±41.72 mg/kg was found in Acha (Fonio), was higher than the 27.50 mg/kg Fe value recorded for black Fonio (Acha) from Kano City, Nigeria (Sadiq *et al.*, 2015), but lower than the 148.2±50.10 mg/kg recorded in Acha from Plateau State in north-central Nigeria (Glew *et al.*, 2013), and 346±142 mg/kg mean Fe value recorded for white Fonio (Acha) in Mali (Koreissi-Dembélé *et al.*, 2013). Generally, none of the values recorded for Fe in this study exceeded the acceptable 425.50 mg/kg Fe limits of FAO/WHO in foods (FAO/WHO, 2022).

Mn Concentration in the Studied Cereal Samples

Manganese is an essential element that is important for growth, blood-clotting factors, skeletal formation and reproduction in humans and animals and its deficiency can lead to diabetes, bone disorder, stunted growth and nervous system instability in infants and children; and arthritis in adults (Umar *et al.,* 2023; Hamid *et al.*, 2020; Rehman *et al.*, 2017; Saraf and Samant, 2013). The overall Mn concentration in the studied composite cereals ranged between 1.58 mg/kg in foreign rice and 38.33 mg/kg in wheat. The highest mean concentration of Mn in the studied composite cereals was found in wheat (33.24±4.85 mg/kg), while the lowest was in foreign rice (3.46±2.29 mg/kg). The mean Mn concentrations in the composite cereals are in the order: Wheat > Sorghum > Millet > Acha > Local Rice > Maize > Foreign Rice.

Maize recorded a mean Mn concentration of 5.25±2.45 mg/kg. This was similar to the 5.4±0.6 mg/kg mean Mn value obtained in yellow Maize from Jos, Nigeria (Ikem *et al.,* 2023), but lower than the 10.00±0.10 mg/kg mean Mn value recorded for Maize in Poland (Grembecka and Szefer, 2022). However, Sorghum recorded higher mean Mn concentrations of 14.49±6.08 mg/kg which was above the 10.75 mg/kg mean Mn obtained in Indian sorghum by Shobha and Kalshetty (2017). This value was also higher than the 13.0±0.6 and 10.0±0.87 mg/kg respectively recorded for white and red Sorghum from Jos, Nigeria (Ikem *et al.,* 2023), but lower than the 16.0 mg/kg recorded for Indian sorghum (Chandra *et al.,* 2016).

Local rice and Acha recorded a close mean Mn concentration of 8.10±2.43 and 8.25±7.06 mg/kg respectively. These were lower than the 36.91 mg/kg mean Mn obtained in improved rice varieties on which chemical fertilizer was used in Sri Lanka

(Rajatheja *et al.*, 2020) and 14.80±6.30 mg/kg recorded in Acha from Plateau State, North-central Nigeria (Glew *et al.*, 2013). The values were however higher than the 7.15±4.93 mg/kg mean Mn values recorded for Cape Verde rice (Rubio-Armendáriz *et al.*, 2022). Foreign rice in this study, on the other hand, had a lower mean Mn concentration of 3.46±2.29 mg/kg which is similar to the 3.30 mg/kg obtained in Indian rice (Al-khamaiseh *et al.*, 2025).

Millet had a mean Mn concentration of 10.86±2.61 mg/kg, which was higher than the 6.87±1.85 mg/kg mean Mn obtained in millet from Beijing, China (Wei and Cen, 2020), but lower than the 11.6±2.8 and 11.90 mg/kg mean Mn respectively obtained in Pearl Millet from Jos, Nigeria and in Libyan millet (Ikem et al., 2023; Shaban and Mokhtar, 2016). While wheat had a mean Mn concentration of 33.24±4.85 mg/kg which is lower than the 44.30±1.20 mg/kg mean Mn recorded in Polish hulled wheat by Grembecka and Szefer, (2022) and 51.25 mg/kg mean Mn recorded in Indian wheat (Shobha and Kalshetty, 2017). Also generally, all the 28 composite cereals from the 4 main markets in Minna metropolis in this study, representing 100 %, had Mn content below the acceptable 500.00 mg/kg Mn limits of FAO/WHO in foods (FAO/WHO, 2022).

Cr Concentration in the Studied Cereal Samples

Chromium is needed for the biosynthesis of glucose tolerance factor and maintenance of normal blood glucose levels. Biologically active trivalent Cr(III) is found in foods, and is effective in the management of diabetes and is a cofactor with insulin; while toxic and carcinogenic hexavalent Cr(VI) results from industrial pollutions. (Umar *et al.,* 2023; Falah and Saja, 2017; Prashanth *et al.,* 2015). The overall Cr concentration in the studied composite cereals ranged between ND (in some samples) and 9.95 mg/kg in Acha. The highest mean concentration of Cr in the analysed composite cereals was found in Acha (3.69±4.23 mg/kg), while the lowest was in maize (0.06±0.08 mg/kg). The mean Cr concentrations in the studied composite cereals were in the order: Acha > Sorghum > Wheat > Millet > Local Rice > Foreign Rice > Maize.

Maize had a Cr mean concentration of 0.06±0.08 mg/kg. This was similar to the 0.070±0.001 mg/kg recorded for maize from Waja village in Hong Local Government Area of Adamawa State, Nigeria (Micah *et al.,* 2024). It was however lower than the 0.10±0.01 and 1.80±0.33 mg/kg mean Cr values respectively recorded for Maize in Poland (Grembecka and Szefer, 2022) and Bangladesh (Islam *et al.,* 2015). Sorghum and wheat had comparable mean Cr concentration of 1.60±1.91 and 1.59±2.32 mg/kg respectively, which were higher than the 0.95±0.02 mg/kg mean Cr obtained in Ethiopian sorghum (Tegegne, 2015). It is also higher than the 0.52±0.22 and 0.28±0.11 mg/kg mean Cr respectively obtained in white and red sorghum from Jos, Nigeria (Ikem *et al.*, 2023). The mean concentrations of Cr in local and foreign rice were 0.29±0.07 and 0.14±0.17 mg/kg respectively. These were much higher than the 0.025±0.024 mg/kg mean Cr recorded for rice in Beijing, China (Wei and Cen, 2020), but lower than 1.80±1.40 mg/kg mean Cr values recorded for rice in Bangladesh (Islam *et al.*, 2015) and the 87.6±61.0 mg/kg mean Cr value recorded in an Iranian study of rice from four countries (Amarloei *et al.*, 2024). Millet and Wheat had mean Cr concentration of 0.64±0.39 and 1.59±2.32 mg/kg respectively. These values were higher than the 0.053±0.017 mg/kg mean Cr obtained in Millet in Beijing, China (Wei and Cen, 2020), but lower than 2.23 mg/kg obtained in a study of black finger millet from Jos, Nigeria by Glew *et al*. (2013). The 0.21±0.09 mg/kg Cr value recorded for Acha from Plateau State in north-central Nigeria (Glew *et al.*, 2013) was lower than the 3.69±4.23 mg/kg mean Cr obtained in Acha in this study. Generally, only 4 of the 28 analysed composite cereals, representing 14.3 %, had values exceeding the acceptable 2.30 mg/kg Cr limits of FAO/WHO in foods (FAO/WHO, 2022).

Pearson's Correlation

Pearson's correlation analysis was used to measure the interdependent association between studied metals. Positive correlations were observed among the studied metals indicating a direct relationship between the variables such that both variables increase or decrease together. A correlation coefficient value of 1 indicates a perfect correlation while zero (0) indicates no correlation or no relationship between the two variables (Umar *et al.*, 2023; Salau *et al.*, 2020; Oral *et al.*, 2018).

Table 5 showed the correlation matrix / coefficient of the 5 metals in the studied cereal samples. High positive correlations are observed between Zn and Cu (0.797); moderate positive correlations are observed for Fe/Cr (0.671), Cu/Mn (0.659) and Zn/Mn (0.538). While low (weak) positive correlations are observed for the remaining metal associations. Positively correlated metals imply that if increasing the consumption of the cereal food samples will favour the increase of one metal (that may be deficient), the second correlated metal will as well be favourably gained along; similarly, a decrease in the metal goes along with the decrease in the other correlated metal. So, care must be taken especially when there is the risk of the other being toxic or in excess (like Fe/Cr). This information could help to know if the consumption of certain desirable mineral element might carry along the undesirable element, as in the case of Fe/Cr. It also helps in identifying the signature or characterization of the general profile of the samples, as elements with strong correlations in food quality control studies, often represent the signature of the food samples (Umar *et al.*, 2023; Salau *et al.*, 2020; Hassan *et al.*, 2019; Salau and Hasan, 2019; Salau and Hasan, 2018). Hence, Zn/Cu with probability value of 0.797,

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it implies that about 80% of the samples have Zn/Cu correlated; Implying that the samples contain Cu & Zn as principal components.

Chemometrics

The versatile statistical chemometrics software (Solo Workspace Browser) was used for the Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) to analyse the results obtained in this study to reveal some latent features.

The Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) of the studied cereals data (from the 4 markets in Minna metropolis) had a computational matrix of dimension (28 x 5). Ward's method was used and it was auto-scaled before applying other PCA procedures (Salau and Hasan, 2019; Salau *et al.*, 2020; Umar *et al.*, 2023). From the processed data, the two Principal Components (PC1 and PC2) that retained the maximum variabilities and similarities of the food samples produced are shown on Table 7:

Table 7: Percent Variance Captured by PCA Model

Principal Component Number	Eigenvalue of Cov (X)	% Variance Captured This PC	% Variance Captured Total
1	2.68e + 00	53.66	53.66
2	1.08e + 00	21.57	75.23

The Hotelling T^2 (figure 2) revealed samples with unusual features. Samples with comparable metal proportions were seen to have navigated towards the origin, while those with unusual proportions or features (cereals labeled 28, and 23) stand out. Hence, these three samples have unusual metal concentrations, e.g., sample 28 (Acha from Bosso Mkt) has the highest Cr and very high Fe concentrations, sample 23 (Bosso Sorghum) has the highest Fe value.

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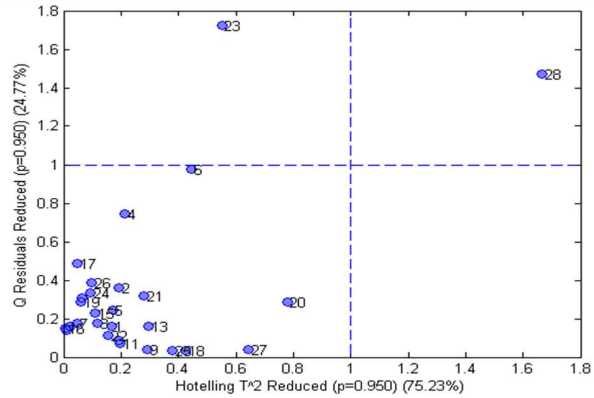

Figure 2: PCA Hotelling T2 Plot of Analysed Data of the 28 Cereal Samples from the 4 Major Markets in Minna metropolis. **Key:** [1. Kure Maize 2. Kure Sorghum 3. Kure L/Rice 4. Kure F/Rice 5. Kure Millet 6. Kure Wheat 7. Kure Acha 8. Gwari Maize 9. Gwari Sorghum 10. Gwari L/Rice 11. Gwari F/Rice 12. Gwari Millet 13. Gwari Wheat 14. Gwari Acha 15. Chanchaga Maize 16. Chanchaga Sorghum 17. Chanchaga L/Rice 18. Chanchaga F/Rice 19. Chanchaga Millet 20. Chanchaga Wheat 21. Chanchaga Acha 22. Bosso Maize 23. Bosso Sorghum 24. Bosso L/Rice 25. Bosso F/Rice 26. Bosso Millet 27. Bosso Wheat 28. Bosso Acha]

However, the PCA Biplot (Figure 3) which simultaneous considered both the score matrix (food types) and the loading matrix (trace metal concentration) is more advantageous as it revealed more or clearer information. The Biplot indicated the correlated elements with the food samples. The PC1 (53.66 % Variance Captured) and PC2 (21.57 % Variance Captured) produced a biplot with three major groups. The first consist of cereals labeled 23, 9, 21, 14, and 28. They are Cr and Fe rich foods. The second consists of cereals labeled 5, 26, 7, 13, 27 and 20. They are Zn, Cu and Mn rich foods. While the third consists of cereals labeled 1, 25, 4, 11, 22, 15, 24 and 10 which are particularly low in concentrations of the studied trace metals. This biplot result shows the foods with relevant elements that can be useful in the choice for management of mineral deficiency diseases as suggested in a similar work by Salau *et al.* (2020). However, the biplot also has shortcomings as some of the samples are not so visible due to their overlap on each other.

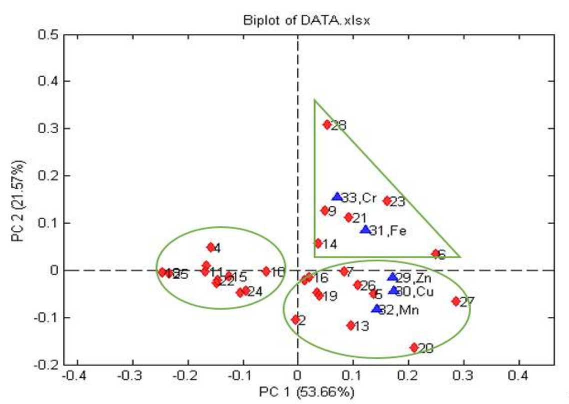

Figure 3: PCA Biplot (Score Loading) of Analysed Data of the 28 Cereal Samples from the 4 Markets in Minna metropolis. **Key:** [1. Kure Maize 2. Kure Sorghum 3. Kure L/Rice 4. Kure F/Rice 5. Kure Millet 6. Kure Wheat 7. Kure Acha 8. Gwari Maize 9. Gwari Sorghum 10. Gwari L/Rice 11. Gwari F/Rice 12. Gwari Millet 13. Gwari Wheat 14. Gwari Acha 15. Chanchaga Maize 16. Chanchaga Sorghum 17. Chanchaga L/Rice 18. Chanchaga F/Rice 19. Chanchaga Millet 20. Chanchaga Wheat 21. Chanchaga Acha 22. Bosso Maize 23. Bosso Sorghum 24. Bosso L/Rice 25. Bosso F/Rice 26. Bosso Millet 27. Bosso Wheat 28. Bosso Acha, 29, Zn 30. Cu 31. Fe 32. Mn 33, Cr]

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Hierarchical Cluster Analysis (HCA)

The Hierarchical Cluster Analysis (HCA) builds hierarchy of clusters between the samples and compares distances between pairs of samples. Similar samples (in terms of mineral element contents) have closer distances between their clusters, while the more dissimilar samples have farther distances between themselves (Salau *et al.,* 2020; Umar *et al.,* 2023). The HCA easily reveals close substitute foods in terms of similarity of mineral element contents as shown in some similar other studies that revealed the similarity and closeness of the foods to be illustrated by cluster analysis (Brereton, 2009; Salau *et al.,* 2020).

Figure 4 is the dendrogram obtained from the HCA of the data of the mean values of the 28 composite cereal samples in this study. Three major clusters of 11, 12, and 5 membership sizes respectively are depicted on the dendrogram. The first cluster comprises cereals labelled as 1, 22, 15, 4, 8, 11, 3, 24, 10,18, and 25. The second consists of cereals labelled as 2, 13, 12, 16, 17, 19, 5, 26, 7, 6, 27 and 20. While the third comprised of samples 9, 21, 14, 23 and 28. Nine sub-groups are also revealed in the dendrogram.

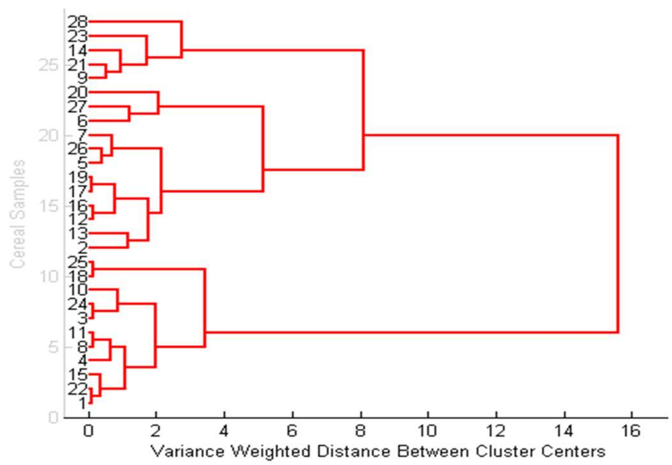

Figure 4: Hierarchical Cluster Analysis (HCA) Dendrogram of Analysed Data of the 28 Cereal Samples from the 4 Markets in Minna metropolis. **Key:** [1. Kure Maize 2. Kure Sorghum 3. Kure L/Rice 4. Kure F/Rice 5. Kure Millet 6. Kure Wheat 7. Kure Acha 8. Gwari Maize 9. Gwari Sorghum 10. Gwari L/Rice 11. Gwari F/Rice 12. Gwari Millet 13. Gwari Wheat 14. Gwari Acha 15. Chanchaga Maize 16. Chanchaga Sorghum 17. Chanchaga L/Rice 18. Chanchaga F/Rice 19. Chanchaga Millet 20. Chanchaga Wheat 21. Chanchaga Acha 22. Bosso Maize 23. Bosso Sorghum 24. Bosso L/Rice 25. Bosso F/Rice 26. Bosso Millet 27. Bosso Wheat 28. Bosso Acha]

From the HCA dendrogram, pairs of cereals could be observed as close substitutes based on their trace metal contents. Maize from Kure and Bosso markets (1/22), Local rice and Millet from Chanchaga market (17/19), and Foreign rice from Chanchaga and Bosso markets (18/25) were close pairs and substitutes for one another. The other close pairs were Local rice from Kure and Bosso markets (3/24), Millet from Gwari market and Sorghum from Chanchaga market (12/16), and Maize and Foreign rice from Gwari market (8/11). This observation implies that in cases of cost, unavailability, scarcity of one of the pairs, or taste preference, the consumption of the other pair can be done because each pair contain similar or close equivalent trace metal contents as similarly observed in other works (Salau *et al.,* 2020; Umar *et al.,* 2023; Gere *et al.,* 2015; Oliveira *et al.,* 2014).

Conclusion and Recommendation

The results showed a wide variation in concentrations of the studied trace metals in the samples with Cr not being detected in 6 of the 28 analysed composite cereal samples. Across the 28 composite cereal samples (from the 4 major markets in Minna metropolis), Fe (66.96±48.52 mg/kg) had the overall maximum mean concentration while Cr had the lowest mean concentration (1.14±2.12 mg/kg), with the overall individual mean metal concentrations in the order: Fe > Zn > Mn > Cu > Cr.

Pearson's correlation analysis showed high positive correlations between Zn and Cu (0.797); moderate positive correlations were observed for Fe/Cr (0.671), Cu/Mn (0.659) and Zn/Mn (0.538). While low (weak) positive correlations are observed for the remaining metal associations. The PCA Biplot revealed three major groups with Sorghum from Bosso & Gwari markets, Acha from Chanchaga, Gwari & Bosso markets (labeled 23, 9, 21, 14, and 28) as being Cr and Fe - rich foods. Millet from Kure & Bosso markets, Acha from Kure market, and Wheat from Gwari, Bosso & Chanchaga markets (labelled 5, 26, 7, 13, 27 and 20) that are Zn, Cu and Mn rich foods. While other cereals (labeled 1, 25, 4, 11, 22, 15, 24 and 10) are particularly low in concentrations of the studied trace metals.

The HCA produced a dendrogram with three major clusters of 11, 12 and 5 membership sizes respectively, from which closely substitutable pairs of cereals were observed based on their trace metal contents. Maize from Kure and Bosso markets (1/22), Local rice and Millet from Chanchaga market (17/19), and foreign rice from Chanchaga and Bosso markets (18/25) were close pairs and substitutes for one another. The other close pairs were Local rice from Kure and Bosso markets (3/24), Millet from Gwari market and Sorghum from Chanchaga market (12/16), and Maize and Foreign rice from Gwari market (8/11).

Except for only 4 of the examined samples that had Cr with values above recommended standards, all the other studied metals in the 28 composite cereals from the 4 major markets in Minna metropolis had concentration values below the acceptable limits of FAO/WHO in foods, suggesting their relative safety for the consumption. However, the four high Cr values are of concern since Cr (VI) is toxic and harmful to health, especially with prolonged consumption of the cereals. The high Cr values may be due to the local soil characteristics or contamination from atmospheric depositions and other farming practices where these cereals were grown, transported, or sold (Umar *et al.*, 2023; Biose *et al.*, 2020; Melnikov *et al.*, 2016).

Hence, there is the need for government regulations on sanitary measures on where and how these cereals are grown, transported and sold. There is also the need for adequate periodic monitoring and implementation of necessary measures to regulate and curb excessive intake of trace metals by consumers. Such periodical studies should incorporate more foodstuff, more food groups, and more trace / major elements, to promptly ascertain their wholesomeness and safety to consumers.

Declaration of Competing Interest

All authors declare that they have no conflict of interest regarding this publication. Also, that this work is original research and has not been published, nor submitted for publication elsewhere.

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