PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (11) 2561-2567 November 2023

Evaluation of Essential Metal Concentration and Possible Potential Health Risk in Chicken Giblets Commonly Sold to Consumers in Lokoja Main Market, Kogi State, Nigeria

***EMUROTU, JE; HABIB, L**

Department of Chemistry Federal University Lokoja, Lokoja, Kogi State, Nigeria

**Corresponding Author Email: jude.emurotu@fulokoja.edu.ng*
Co-Author Email: lamihabib@yahoo.com

ABSTRACT: The objective of this work was to evaluate the concentrations of essential metals (K, Na, Ca, Mg, Fe, Cu, Se, B, P, and Zn) and potential health risks in chicken giblets commonly sold to consumers in Lokoja's main market, Kogi State, Nigeria. Using appropriate standard methods, samples were digested with 65% HNO_3, and the digest was analyzed using an Inductively Coupled Plasma-Optical Emission Spectrometer. The mean concentrations (mg/kg) in gizzard ranged from 0.06±0.08 (Cu) to 28.1±6.9 (P), kidney 0.04±0.01 (Cu) to 24±10 (P), and liver 0.09±0.10 (Cu) to 47±11(P). All the essential metals examined were below the FAO and WHO's permissible standards. The observed trend in the accumulation of metal concentration in chicken giblets was P > Na > Ca > Fe > Mg > Zn > B > Se > K, Cu. The health risk analyses revealed that the current exposure levels will not have a major negative impact on human health, as the hazard quotient for each metal was less than one (<1) and the overall hazard index was also less than 1. Although the population will not be exposed to the potential health risks from these metals presently, there is a need to regularly assess the levels of heavy metals in chicken giblets to maintain protection against negative health effects.

DOI: https://dx.doi.org/10.4314/jasem.v27i11.27

Cite this paper as: EMUROTU, JE; HABIB, L (2023). Evaluation of Essential Metal Concentration and Possible Potential Health Risk in Chicken Giblets Commonly Sold to Consumers in Lokoja Main Market, Kogi State, Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (11) 2561-2567

Dates: Received: 30 September 2023; Revised: 29 October 2023; Accepted: 07 November 2023 Published: 30 November 2023

Keywords: chicken giblets; essential metals; daily intake; health risk.

Meat is an excellent source of protein as it contains essential metals and vitamins humans need (Emami *et al*., 2023). One of the most widely consumed meats worldwide is chicken meat as it serves as a source of essential nutrients chiefly protein, in addition to minerals, vitamins, and fats (Bratty *et al*.,s 2018). Chicken meat is a vital source of essential metals like iron, selenium, copper, zinc, vitamins and folic acid normally obtained from plant-derived foods or their availability from plants is poor. As such, doctors frequently recommend chicken meat as a source of these essential metals for patient. Chicken meat has a low glycemic index due to its protein content and low carbohydrate content, which is thought to protect against the development of diabetes, obesity, and cancer (insulin resistance hypothesis). Chicken meat is a necessary component of a balanced diet because it guarantees proper supply of important micronutrients and amino acids sand participates in energy metabolism regulation activities (Ullah *et al*., 2022). Trace metals present during processing and environmental contamination brought on by human activity could impact the quality of the chicken meat. Arsenic, aluminum, mercury, lead, and cadmium are examples of trace elements that can be classified as hazardous metals and accumulate in meat, posing a risk to human health even in low amounts (Alsohaimi, 2023).

Long-term exposure to environmental pollution causes around 25% of the diseases that affect humans (WHO). Some trace elements are thought to be essential, including zinc, selenium, iron, manganese, and copper, which are important for human biology, metabolism, and physiology. However, these vital trace minerals may have negative consequences at higher doses. Muscle weakness, nausea, and growth retardation are health problems caused by excessive Mn intake.

**Corresponding Author Email: jude.emurotu@fulokoja.edu.ng*

Wilson's disease and acute gastrointestinal issues can also be caused by long-term exposure to high levels of copper (Alsohaimi, 2023). Overconsumption of zinc may have an immunosuppressive impact and encourage the growth of infections (Li *et al*., 2022), high-density lipoprotein (HDL) levels in healthy men are demonstrated to decline. Human immunological issues, skin abnormalities, neonatal development retardation, and appetite loss have all been linked to Zn deficiency (Gunasekara *et al*., 2011; Mohamed *et al*., 2019). There exists a physical-chemical relationship between zinc and insulin (Gunasekara *et al*., 2011). Selenium is one micronutrient whose toxic concentrations and deficiency are very closely correlated. In order to establish the proper balance of Se in humans and animals, it is crucial to understand its abundance or deficiency in food and diet. The bioavailability of the nutrient must be considered because estimates of the total element content of a given food are typically unreliable. Knowing an element's bioavailability, or the amount absorbed and used by the organism, is important because, typically, only a small portion is absorbed and converted into a form that is biologically usable (Navarro-Alarcon and Cabrera-Vique, 2008). For instance, a lack of selenium is linked to Kashin-Beck illness, cardiovascular problems, hypothyroidism, and a compromised immune system, whereas an excess of selenium causes neurological abnormalities and generalized weakness (Mohamed *et al*., 2019). It has been established that essential elements are necessary for the proper functioning of the human system, however, excessive intake or deficiency of them affects human health. Thus, the objective of this work was to assess the concentrations of essential metals (K, Na, Ca, Mg, Fe, Cu, Se, B, P, and Zn) and possible potential health risks in chicken giblets commonly sold to consumers in Lokoja's main market, Kogi State, Nigeria.

MATERIALS AND METHOD

Sample area and Sample Collection: Briefly, the study location was Lokoja Kogi State capital, Northcentral Nigeria. Lokoja is located between latitudes 7° 45' 27.56" and 7° 51' 04.34" N and 6° 41' 55.64" and 6°45' 36.58" E. Its total land area is roughly 63.82 square kilometers. A total of 90 chicken giblets (bought chicken) each of liver, gizzard, and kidney were collected from the old market (which houses both the poultry market and slaughterhouse) in Lokoja. Samples were analyzed by using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). ICP-OES was used for the analysis of essential trace elements in foods because it has a lower detection limit and high efficiency compared to atomic absorption spectroscopy (AAS).

Sample Pre-treatment: Each sample was cleaned in the lab using distilled deionized water. Using a stainless-steel knife, each part was cut into slices and spread out in the lab to dry at room temperature. Following the procedure outlined by Oforka et al. (2012), each sample was dried at 105°C to a constant weight in an oven (Memert GmbH+Co.KG, Germany) ensuring no physical damage changes like heat burn, and then the samples were ground using a porcelain mortar and pestle, sieved with a < 2mm mesh and stored in labelled polyethylene and kept in a desiccator before digestion (Oforka *et al*., 2012).

Digestion of giblets samples: Each dried sample of chicken giblet powder (0.5 g) was transferred into a Teflon flask and digested at 120 °C for 8 hours on a hot plate electronic equipment (Yellow-line MAG HS 7; IKA, Holland) with 10 ml of 65% HNO_3 (Sigma-Aldrich, St. Louis, MO, USA) until dense white vapour emerged. This procedure is deemed appropriate since it helped prevent losses caused by the volatilization of the relevant metals (Chijioke *et al.*, 2020; Enamorado-Báez *et al*., 2013). The digest was allowed to cool and filtered into a 50 mL standard flask and made to mark with distilled deionized water.

Metal analysis: An Inductively Coupled Plasma Optica Emission Spectrometer (ICP-OES) (Perkin Elmer Optical 8000, France) was used to determine K, Na, Ca, Mg, Fe, Cu, Se, B, P, and Zn concentrations in the digest. The operating conditions of the ICP-OES are: RF power 1500 W, plasma gas flow rate 15 L/min, auxiliary gas flow rate 1.5 L/min, nebuliser gas flow rate 0.94 L/min dwell time 0.01 s, total time for each measurement 3 min.

Quality assurance: The accuracy and veracity of the results obtained were confirmed using the proper safety precautions and quality control techniques. Sample handling was done with enough care to avoid cross-contamination. Every piece of used glassware was meticulously cleaned. Double distilled deionized water and analytical grade chemicals were used in all stages of sample preservation, preparation, and metal analysis. Each batch of samples was run along with a blank and a set of combined standards to ensure consistency between batches and detect background contamination to evaluate the dependability of the analytical method for metal determination. Recovery tests were conducted to examine the analytical procedure's accuracy and precision. This was accomplished by comparing the metal concentrations in replicate samples of spiked and unspiked sample (Ajah *et al*., 2022). Mean recoveries attained ranged from 91.0±2.3% to 97.7±4.3%. Limit of detection (LOD) was calculated as described by Shrivastava and Gupta (2011). The limit of detection for Ca, K, Na, Mg, Fe, Cu, Se, and Zn mg/L are 0.0017, 0.0002, 0.0005, 0.0001, 0.0628, 0.0001, 0.0004, and 0.0012, respectively.

Assessment of Health Risk: Estimated Daily Intake (EDI): EDI of metals determined in mg/kg bw/day was calculated as in Eq. (1) (Chijioke *et al*., 2020s).

$$EDI = \frac{M_c \times R_{It}}{B_w} \quad (1)$$

Where M_c is the mean concentration of each metal (mg/kg dry weight), R_{It} is the intake rate and B_w is the body weight. B_w of an adult individual stand for 70 kg (Chijioke *et al*., 2020). Data obtained from FAOSTA (FAOSTA 2001) showed that the average daily consumption of chicken meat in Nigeria was 1.16 kg (= 3.18 g/day) in 2020. If the average amount of chicken giblets in chicken flesh is less than 10%, the Nigerian population would consume roughly 0.32 g of chicken giblets each day. As a result, the ingestion rate is roughly equivalent to the 0.32 g (0.32×10^{-3} mg/kg) of chicken giblets that the Nigerian populace consumes each day.

Estimation of average daily dose: The average daily dosage (ADD) is used to assess the amount of exposure to food residues that people are exposed to. The ADD (mg/kg/day) for a particular residue contained in chicken giblets ingested, as given in Eq. 2, can be calculated using the formula below (Chijioke *et al*., 2020),.

$$ADD = \frac{EDI \times P_T \times E_F}{T_P} \quad (2)$$

Considering those that consumed chicken giblets four days a week in the area based on the local information obtained, EDI the intake of metal from consuming chicken giblets, P_T is the period of time an individual is exposed to ingested metals during a lifetime (70 years, commensurate with the average life span of the Nigerian population), and EF is the exposure regularity (200 days/year). Additionally, T_p (the number of days over which the dose is averaged in days) is commonly thought of as being equal to EF (=$365\times P_T$) for non-carcinogenic effects.

Hazard quotient (HQ): The HQ categorizes the human health risks based on non-cancerous risk. The equation listed below was used to calculate in Eq. 3 (Mahmoud and Abdel-Mohsein, 2015).

$$HQ = \frac{ADD}{RfD} \quad (3)$$

HQ represent hazard quotient, RfD is the oral reference dose for each unique metal. HQ scores below one implies minimal carcinogenic risks. The RfD values for determined metals are: Mg (0.140), Fe (0.70), Cu (0.04), Se (0.005), and Zn (0.3), while K, Na, Ca, B, and P are not specified. The long-term exposure, however, poses serious health risks if it is larger than one (>1) (Chijioke *et al*., 2020; USEPA 2017). The HI is used to measure the overall noncarcinogenic health risks of a mixture of hazardous chemicals (hazard index). As a result, HI is defined as the sum of all estimated HQ values for different metals in the equation 4.

$$HI = \sum_{n=1}^{n} HQ_S \quad (4)$$

RESULTS AND DISCUSSION

Essential metal concentrations in chicken giblets: Presented on Table 1 is the range and mean concentrations of essential metals in giblets of chicken from Lokoja. Of the determined essential metals in giblets of chicken, P was the most abundant, with concentrations that ranged from 8.99 – 35.9 mg/kg in gizzard, 4.51- 37.1 mg/kg in Kidney, and 27.4 – 69.0 mg/kg with mean values of 28.1±6.9, 24±10, and 47±11mg/kg respectively. The body needs phosphorus for several vital processes thus getting enough of it is excellent for health.

Possible health advantages include maintaining healthy bones and teeth, assisting in muscular contractions, and more (Fletcher, 2019). It is well recognized that copper (Cu) plays an important role in the development of bone, skeletal mineralization, and the efficient functioning of connective tissues. Copper is a crucial component of many different enzymes in both people and animals; it accumulates mostly in muscle and the liver and serves as a necessary element.

Copper overload is a pathological issue in Wilson's illness and Menke's even if there is little evidence of chronic copper toxicity. Additionally, copper is not being adequately removed from the body (Chijioke *et al*., 2020; Elsharawy, 2018). The highest mean concentration (0.09±0.10 mg/kg was found in the liver). The concentrations in the gizzard and Kidney were 0.06±0.08 and 0.04±0.01 respectively. Elsharawy has also reported the highest concentration of Cu in the liver of chicken (Elsharawy 2018).

The mean concentrations of this study are lower than values reported in chicken giblets in Egypt (Elsharawy, 2018), Malaysia (Chijioke *et al*., 2020), Iraq (Aljaff *et al*., 2014), Nigeria (Onyeka and David, 2015), and the permissible limit of 40 mg/kg in foodstuffs recommended by CODEX Alimentarius Commission (2016). Calcium is an essential element utilized for creating bone tissue, eggshells, maintaining the acid-base balance, and the enzyme system.

Its deficiency often led to skeletal deformities, rickets, neurological weakness, tibial dyschondroplasia and others (Xing *et al*., 2020). In this study, the concentration of Ca in chicken giblets ranged from 7.40 –26.4 mg/kg. The highest mean concentration of 20.0±4.5 mg/kg was found in gizzard, followed by liver (19.7±4.3 mg/kg), and the lowest was in kidney with a mean of 12.9±3.8 mg/kg.

Table 1: Concentrations of metal in chicken giblets and estimated daily intake (EDI) (mg/kg/bw /day) for adult due to the Consumption of metals in chicken giblets.

Metal	Range (mean ± sd) concentrations in mg/kg			Estimated Daily Intake (µg/kg/day)		
	Gizzard (n = 90)	Kidney (n = 90)	Liver (n = 90)	Gizzard	Kidney	Liver
Ca	14.1-26.4(20.0±4.5)	7.40-19.7(12.9±3.8)	13.0-27.5(19.7±4.3)	9.14E-02	5.60E-02	9.01E-02
Na	14.0-29.7(20.3±5.4)	7.82-32.9(19.0±7.4)	7.82-41.6(24±10)	9.28E-02	8.69E-02	1.10E-01
K	0.10-0.16(0.12±0.02)	0.01-0.14(0.07±0.04)	0.01-0.18(0.11±0.04)	5.49E-04	3.20E-04	5.03E-04
Mg	4.57-7.61(6.33±0.89)	0.41-7.85(3.8±2.3)	3.35-9.22(6.3±1.5)	2.89E-02	1.74E-02	2.88E-02
Fe	2.61-35.0(14±13)	0.66-19.2(5.2±5.6)	1.67-37.9(9±11)	6.40E-02	2.38E-02	4.11E-02
Cu	0.02-0.33(0.06±0.08)	0.02-0.06(0.04±0.01)	0.04-0.39(0.09±0.10)	2.74E-04	1.83E-04	4.11E-04
B	0.09-0.53(0.34±0.14)	0.27-0.74(0.50±0.16)	0.01-0.78(0.17±0.24)	1.55E-03	2.29E-03	7.77E-04
Se	0.08-0.40(0.21±0.10)	0.08-0.30(0.17±0.07)	0.15-0.70(0.36±0.17	9.60E-04	7.77E-04	1.65E-03
P	8.99-35.9(28.1±6.9)	4.51-37.1(24±10)	27.4-69.0(47±11)	1.28E-01	1.10E-01	2.15E-01
Zn	0.08-13.2(2.04±3.6)	0.05-13.5(1.9±3.7)	0.08-3.07(1.15±0.77)	9.33E-03	8.69E-03	5.26E-03

The observed concentrations of Na in chicken giblets were similar to values recorded for Ca, but unlike Ca, the highest concentration of Na (24±10 mg/kg) was in the liver. But for K, the concentrations were significantly lower than to Ca and Na. Chicken giblets have been identified as a main source of Fe, Mg, and Zn. These essential metals, when accumulated in the body at the recommended levels established by various standard organizations, provide healthy growth, the building of nutrients, and oxygen transport in organisms (Chijioke *et al*., 2020). It is well known that consuming enough Fe through diet is essential for lowering the prevalence of anemia. Hemoglobin and RBC depend on Fe for their formation. When iron levels increase following a substantial meal, protein becomes saturated. The circulation of this excess free iron in the bloodstream is toxic to the organs it affects (Hossain *et al*., 2023). However, it is well recognized that consuming enough iron in one's diet is essential for lowering the incidence of anemia. This study's mean Fe concentration is less than the permissible limit of 180 mg/kg given by FAO/WHO (2002). The recorded mean concentrations for Fe are 14±13 mg/kg in the gizzard, 5.2±5.6 mg/kg in the kidney, and 9±11 mg/kg in the liver. Similar mean concentrations have been reported in Malaysia (Chijioke *et al*., 2020), whsile higher values were reported in the Dhaka district in Bangladesh (Hossain *et al*., 2023). Mean concentrations of Mg are 6.33±0.89 mg/kg, 3.8±2.3, and 6.3±1.5 mg/kg in gizzard, kidney, and liver, respectively. Although the concentrations in this study are higher than those previously reported for southern Nigeria (Oforka *et al*., 2012), they are still lower than those reported in Malaysia (Chijioke *et al*., 2020) and Serbia (Jokanovi *et al*. 2014) in earlier studies. An element that supports development is zinc (Zn). Many animal species, including humans, suffer from its lack as they develop. The growth-promoting effects of zinc are assumed to be related to how it affects protein synthesis, which is necessary for both cell division and protein and DNA synthesis. For men, the recommended daily intake for zinc is 11 mg, while for women it is 8 mg (Hossain *et al*., 2023). Recorded Zn mean concentrations are 2.04±3.6 mg/kg, 1.9±3.7 mg/kg, and 1.15±0.77 mg/kg, respectively. These values are similar to the reported concentrations in chicken giblets in Malaysia (Chijioke *et al*., 2020), Egypt (Mousa *et al*., 2010), and Iraq (Aljaff *et al*., 2014). But these study concentrations are lower than previous research reports in Malaysia (Abduljaleel *et al*., 2012), Turkey (Uluozlu *et al*., 2009), and Serbia (Jokanovi *et al*., 2014).

Both humans and animals need Se as an important nutrient. It is a part of glutathione peroxides, which protect tissues from oxidative damage. Although selenium is a necessary vitamin, overexposure to it by food or inhalation can have negative consequences for one's health. The capacity of some chemical mutagens to be activated by liver enzymes appears to be affected by selenium (Aljaff *et al*., 2014). Se has a mean concentration (mg/kg) of 0.36±0.17 in the liver, followed by 0.21±0.10 in the gizzard and 0.17±0.07 in the kidney. This result is similar to previous studies in Malaysia (Chijioke *et al*., 2020), Turkey (Uluozlu *et al*.,s 2009), and Iraq (Aljaff *et al*., 2014) but lower than earlier reported values in Malaysia (Abduljaleel *et al*,. 2012). The concentration (mg/kg) of B ranged from 0.01 to 0.78 with a mean of 0.50±0.16 in kidney being the highest. The PCA findings of the giblet's samples and the heavy metal component loadings are diplayed in a biplot in Fig. 1. The fact that PCA clearly separates all the variables in Fig. 1 and that the vectors (lines) are a little lengthy suggests that the first two components accounted for most of the varian ce of all the quantified variables. In Fig. 1, the heavy metal content patterns for the 90 samples are also clearly displayed. Most of the samples were near the origin which represented the mean concentration of all the samples (Wang et al., 2011).

Non-carcinogenic analysis: Presented in Table 1 is the estimated daily intake for the essential metals Ca, K, Na, Mg, Fe, Cu, Se, B, P, and Zn. The level of toxicity of a metal in humans depends on its daily intake. The EDI value of 2.15E-01(P) in the liver was the highest followed by 1.28E-01(gizzard) and 1.10E-01 (Na). A similar EDI value of 1.10E-01 of P was found in the gizzard. The least EDI value of 1.83E-04 (Cu) was found in the gizzard of chicken. The EDI value of metals obtained arising from the ingestion of chicken giblets was lower than the RfD threshold (USEPA 2017) for human consumption of essential metals. Our findings strongly suggest that the chicken giblets the local Lokoja populations consume pose no health risks to them. The average daily dose (ADD) and HQ results are reported in Table 2. These results are often used to measure the probable potential health risk. The HQ values for chicken giblets were commonly below unity, inferring a quite low level of risk to human health (Chijioke et al. 2020). Also, if the values of the metals taken habitually are greater than 10^{-4} (i.e. ADD > 10^{-4}) it shows possible life cancer risk. ADD values ranged from 1.00E-07 (Cu) to 1.00E-03 (P). The ADD value for the metals (Ca, K, Na, Mg, Fe, Cu, Se, B, P, and Zn) in gizzard, kidney, and liver were within permissible threshold hence none of these metals will pose any health risk. A hazard index (HI) level of less than 1 indicates no danger, 1 to 10 indicates a moderate risk, and greater than 10 indicates a higher risk for the consumers (USEPA 2017; Naseri *et al.*, 2021). The HI levels were less than 1, which indicates that the ingested metals in the chicken giblets will pose no harm to the consumers. Fig 2 displays the contribution of each metal to the HI value. Mg is the main contributor with 81%, followed by Se, Fe, Zn, and Cu with 13%, 4%, 1.5%, and 0.5%, respectively of the HI due to the consumption of chicken giblets.

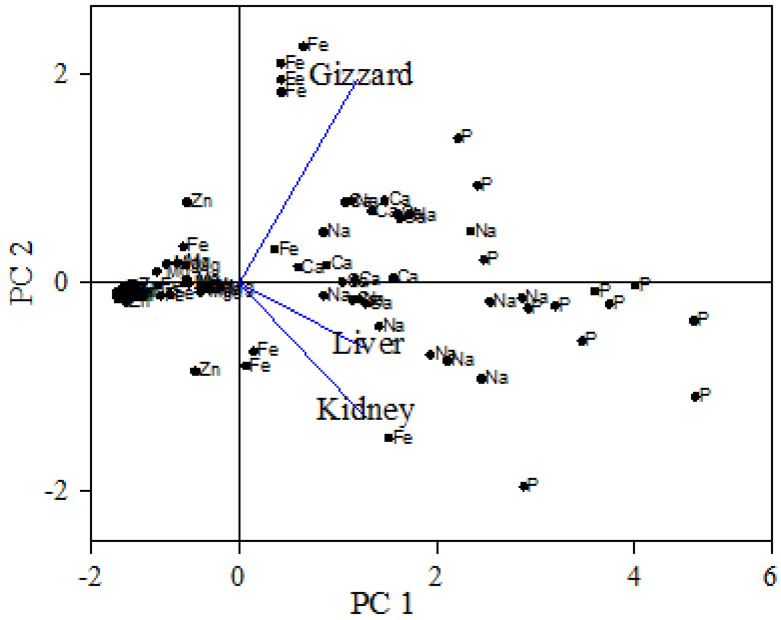

Fig 1: PCA ordination biplot of the 90 samples and heavy metals

Table 2: HQ and HI adult through the consumption of food crops from the study areas

Metal	Average daily dose (ADD) (mg/kg/day)			Non-carcinogenic risk			
				Hazard Quotient (HQ)			Hazard index
	Gizzard	Kidney	Liver	Gizzard	Kidney	Liver	HI=ΣHQs
Ca	5.01E-05	3.07E-05	4.94E-05	-	-	-	
Na	5.08E-05	4.76E-05	6.03E-05	-	-	-	
K	3.01E-05	1.75E-07	2.76E-07	-	-	-	
Mg	1.58E-05	9.53E-06	1.58E-05	1.13E-03	6.81E-05	1.13E-03	2.33E-03
Fe	3.50E-05	1.30E-05	2.25E-05	5.00E-05	1.87E-05	3.21E-05	1.01E-04
Cu	1.50E-07	1.00E-07	2.25E-07	3.75E-06	2.50E-06	5.63E-06	1.19E-05
B	8.49E-07	1.25E-06	4.26E-07	-	-	-	
Se	5.26E-07	4.26E-07	9.04E-07	1.05E-04	8.52E-05	1.81E-04	3.71E-04
P	7.01E-05	6.03E-05	1.00E-03	-	-	-	
Zn	5.11E-06	4.76E-06	2.88E-06	1.70E-05	1.59E-05	9.60E-06	4.25E-05
Hazard index (HI) due to all metals in giblets = *ΣHQs*							2.86E-03

RfD of Ca, Na, K, B, and P is not stated hence no calculation for HQ

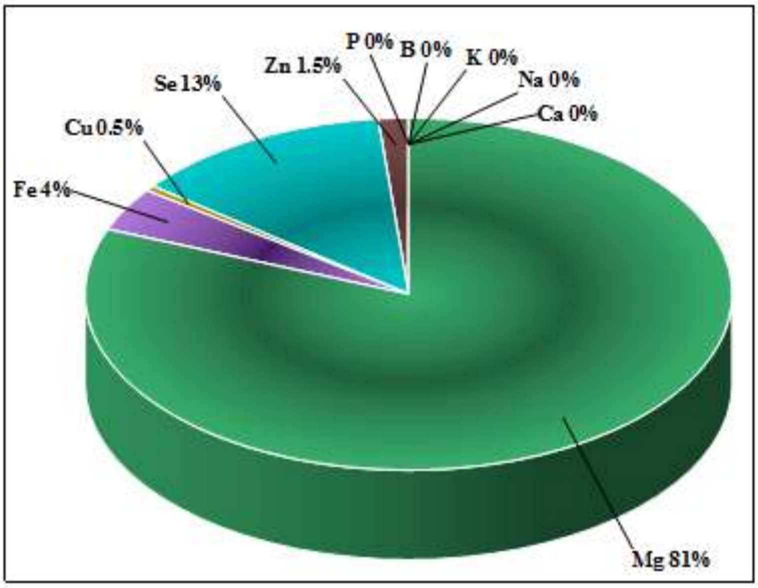

Fig 2: Percentage contribution of each metal to the total HI consumption of the chicken giblets

Conclusion: The concentrations of the essential metals Ca, K, Na, Mg, Fe, Cu, Se, B, P, and Zn assessed in chicken giblets obtained from chicken the main market in Lokoja Kogi State, northcentral Nigeria, were within the maximum allowable concentration limit established by FAO/WHO. The estimated daily intake was lower than the required. Mg made a larger contribution to the giblets' HI value. Current exposure levels will not significantly harm human health because the HQ and HI for each metal was less than unity and the overall hazard index was likewise < 1.

Funding: Authors wish to acknowledge with deep appreciation the financial support of the Tertiary Education Trust Fund (TETFUND), and Federal University Lokoja for the TETFUND Institution Based Research (IBR) grant.

REFERENCE

Abduljaleel, SA; Shuhaiml-Othman, M; Abdulsalam, B (2012). Assessment of Trace Metals Contents in Chicken (Gallus Gallus Domesticus) and Quail (Coturnix Coturnix Japonica) Tissues from Selangor (Malaysia). *J. Environ. Sci. Technol.* 5(6):441–51.

Aljaff, P; Rasheed, BO; Salh, DM (2014) . Assessment of Heavy Metals in Livers of Cattle and Chicken by Spectroscopic Method. *IOSR J. Appl. Phy.* 6(1):23–26.

Al Bratty, AM; Alhazmi, HA; Ogdi, SJ; Otaif, JA; Al-Rajab, AJ; Alam, MF; Javed, SA (2018). Determination of Heavy Metals in Various Tissues of Locally Reared (Baladi) Chicken in Jazan Region of Saudi Arabia: Assessment of Potential Health Risks. *Pak. J. Zool.* 50(4):1509–17.

Alsohaimi, IH (2023). Quantitative Determination of Trace Elements in Frozen and Chilled Chicken Using ICP OES and Related Health Risk Assessment. *J. Taibah Univ. Sci.* 17(1): 2196235

Atique, UA; Shazia, A; Mozammal, M; Maesha, M; Tania, F; Quamrun, N; Quraishi, SB. (2022). Concentration, source identification, and potential human health risk assessment of heavy metals in chicken meat and egg in Bangladesh. *Environ. Sci. Pollut. Res. 29*(15): 22031-22042.

Chijioke, NO; Khandaker, MU; Tikpangi, KM; Bradley, DA (2020). Metal Uptake in Chicken Giblets and Human Health Implications. *J. Food Compost Anal.* 85:103332.

CODEX Alimentarius Commission, (2016). General standard for contaminants and toxins in food and feed. CODEX STAN 193–1995

Duncan TB, Klaus D, Alan T (2002). Use of the terms Brecovery^ and Bapparent recovery^ in analytical procedures (IUPAC Recommendations 2002). International Union of Pure and Applied Chemistry. Analytical Chemistry Division, Commission on General Aspects of Analytical Chemistry. Pure Appl. Chem, 74(11):2201-2205.

Elsharawy, NTM (2018). Some Heavy Metals Residues in Chicken Meat and Their Edible Offal in New Valley. *2nd Conference of Food Safety, Suez Canal University, Faculty of Veterinary Medicine* 1:53–60.

Emami, MH; Saberi, F; Mohammadzadeh, S; Fahim, A; Abdolvand, M; Dehkordi, SAE; Mohammadzadeh, S; Maghool, F (2023). A Review of Heavy Metals Accumulation in Red Meat and Meat Products in the Middle East. *J.*

Food Prot. 26(3):100048.

Enamorado-Báez, SM; Abril, JM; Gómez-Guzmán, JM (2013). Determination of 25 Trace Element Concentrations in Biological Reference Materials by ICP-MS Following Different Microwave-Assisted Acid Digestion Methods Based on Scaling Masses of Digested Samples. *ISRN Anal. Chem.* 2013:1–14.

FAO/WHO. Codex CODEX Alimentarius Commission, (2016). General standard for contaminants and toxins in food and feed. CODEX STAN 193–1995 Alimentarius—general standards for contam_inants and toxins in food. Schedule 1: maximum and guideline levels for contaminants and toxins in food. Joint FAO/WHO Food Standards Programme, Codex Committee, Rotterdam, Reference CX/FAC 02/16. 2002.

FAOSTA. 2001. Food Balance Sheets.” *Food and Agriculture Organization of the United Nations: Rome.* 1–99.

Fletcher, J (2019). What are the health benefits of phosphorus? Retrieved on 02/10/2023 from https://www.medicalnewstoday.com/articles/325623.

Gunasekara, P; Hettiarachchi, M; Liyanage, C; Lekamwasam, S (2011). Effects of Zinc and Multimineral Vitamin Supplementation on Glycemic and Lipid Control in Adult Diabetes. *Diabetes Metab Syndr Obes.* 53-60.

Hossain, E; Nesha, M; Alamgir, M; Chowdhury, Z; Rahman, H (2023). Human health risk assessment of edible body parts of chicken through heavy metals and trace elements quantitative analysis. *Plos one*, 18(3): e0279043.

Jokanovi, MR; Tomovi, VM; Jovi, MT; Škaljac, SB; Šojić, BV; Ikonić, PM; Tasić, TA (2014). Proximate and Mineral Composition of Chicken Giblets from Vojvodina (Northern Serbia *Int. J. Innov. Sci. Res.* 8(9): 982-985.

Li, J; Cao D; Huang, Y; Chen, B; Chen, Z; Wang, R; Dong, Q; Wei, Q; Liu, L (2022). Zinc Intakes and Health Outcomes: An Umbrella Review. *Front. Nutr.* 9: 798078.

Mahmoud, MA; Abdel-Mohsein, HS (2015). Health risk assessment of heavy metals for Egyptian population via consumption of poultry edibles. *Adv. Anim. Vet. Sci*, *3*(1): 58-70.

Mohamed, H ; Haris, PI; Brima, EI (2019). Estimated Dietary Intake of Essential Elements from Four Selected Staple Foods in Najran City, Saudi Arabia. *BMC Chem.* 13(3):1–

Mousa, MM; Ewina, MA; Nehad, IS (2010). Risk assessment of some heavy metals in edible chicken giblets. Alexandria J. Vet. Sci. 29 (1): 27–35.

Naseri, K; Salmani, F; Zeinali, M; Zeinali, T (2021). Health Risk Assessment of Cd, Cr, Cu, Ni and Pb in the Muscle, Liver and Gizzard of Hen’s Marketed in East of Iran. *Toxicol. Rep.* 8:53–59.

Navarro-Alarcon, M; Cabrera-Vique, C (2008). Selenium in Food and the Human Body: A Review. *Sci. Total Environ.* 400(1–3):115–41.

Oforka, NC; Osuji, LC; Onwuachu, UI (2012). Assessment of heavy metal pollution in muscles and internal organs of chickens raised in Rivers State, Nigeria. *J. Emerg. Trends Eng. Appl. Sci. 3*(3): 406-411.

Onyeka, O; David, O (2015). Assessment of Selected Heavy Metal Residues in the Kidney, Liver, Muscle and Gizzard of Chickens Raised Within Enugu Metropolis. *Int J Environ Pollut Res.* 3(4):62–66.

Shrivastava, A; Gupta, V (2011). Methods for the determination of limit of detection and limit of quantitation of the analytical methods. Chronicles Young Sci. 2:21-25

Uluozlu, OD; Tuzen, M; Mendil, D; Soylak, M (2009). Assessment of Trace Element Contents of Chicken Products from Turkey. *J. Hazard. Mater.* 163(2–3):982–87.

US-EPA, Regional Screening Levels (RSLs) - Generic Tables), Available at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables (2017).

Wang, Y; Yang, Z; Shen, Z; Tang, Z; Niu, J; Gao, F (2011). Assessment of Heavy Metals in Sediments from a Typical Catchment of the Yangtze River, China. *Environ. Monit. Assess.* 172(1–4):407–17.

Xing, R; Yang, H; Wang, X; Yu, H; Liu, S; Li, P (2020). Effects of Calcium Source and Calcium Level on Growth Performance, Immune Organ Indexes, Serum Components, Intestinal Microbiota, and Intestinal Morphology of Broiler Chickens. *J Appl Poul Res* 29(1):106–20.