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

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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% HNO₃, and the digestion 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 WHO and FAO'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 quotients 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.

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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., 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.
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% HNO₃ (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).
Evaluation of Essential Metal Concentration and Possible Potential

\[ EDI = \frac{M_c \times B_{RI}}{B_w} \quad (1) \]

Where \( M_c \) is the mean concentration of each metal (mg/kg dry weight), \( R_{RI} \) 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 dosage:** 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 \( E_F \) 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×\( P_T \)) 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 HQ 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.

\[ HI = \sum_{n=1}^{n} HQ_n \quad (4) \]

**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.

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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.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Range (mean ± sd) concentrations in mg/kg</th>
<th>Estimated Daily Intakes (µg/kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gizzard (n = 90)</td>
<td>Kidney (n = 90)</td>
</tr>
<tr>
<td>Ca</td>
<td>1.4±0.26 (20.0±4.5)</td>
<td>7.40±1.97 (12.9±4.8)</td>
</tr>
<tr>
<td>K</td>
<td>4.0±0.26 (15.7±4.0)</td>
<td>0.01±0.01 (0.67±0.40)</td>
</tr>
<tr>
<td>Mg</td>
<td>0.57±0.6 (6.6±3.89)</td>
<td>0.41±0.45 (5.4±3.5)</td>
</tr>
<tr>
<td>Fe</td>
<td>2.6±1.35 (0.5±4.13)</td>
<td>0.66±0.92 (5.2±5.6)</td>
</tr>
<tr>
<td>Cu</td>
<td>0.00±0.03 (0.6±0.08)</td>
<td>0.20±0.60 (0.4±0.01)</td>
</tr>
<tr>
<td>B</td>
<td>0.05±0.3 (0.3±0.14)</td>
<td>0.27±0.74 (0.3±0.16)</td>
</tr>
<tr>
<td>Se</td>
<td>0.05±0.3 (0.2±0.10)</td>
<td>0.05±0.3 (0.1±0.07)</td>
</tr>
<tr>
<td>Zn</td>
<td>0.03±0.3 (2.0±0.86)</td>
<td>0.05±0.3 (1.5±0.3)</td>
</tr>
</tbody>
</table>

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 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), while higher values were reported in the Dhaka district in Bangladesh (Hossain et al., 2023). Mean concentrations of Mg are 6.3±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 2.0±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 (Aljafl 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 (Aljafl 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., 2009), and Iraq (Aljafl 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 gillet's samples and the heavy metal component loadings are displayed 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 variance 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.

![PCA ordination biplot of the 90 samples and heavy metals](image)

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

<table>
<thead>
<tr>
<th>Metal</th>
<th>Average daily dose (ADD) (mg/kg/day)</th>
<th>Non-carcinogenic risk</th>
<th>Hazard Quotient (HQ)</th>
<th>Hazard index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gizzard</td>
<td>Kidney</td>
<td>Liver</td>
<td>Gizzard</td>
</tr>
<tr>
<td>Ca</td>
<td>3.01E-05</td>
<td>3.07E-05</td>
<td>1.54E-05</td>
<td>-</td>
</tr>
<tr>
<td>Na</td>
<td>3.08E-05</td>
<td>4.78E-05</td>
<td>6.03E-05</td>
<td>-</td>
</tr>
<tr>
<td>K</td>
<td>3.01E-05</td>
<td>1.75E-07</td>
<td>2.76E-07</td>
<td>-</td>
</tr>
<tr>
<td>Mg</td>
<td>1.58E-05</td>
<td>9.33E-06</td>
<td>1.58E-05</td>
<td>1.13E-03</td>
</tr>
<tr>
<td>Fe</td>
<td>1.30E-05</td>
<td>1.30E-05</td>
<td>2.25E-05</td>
<td>3.00E-05</td>
</tr>
<tr>
<td>Cu</td>
<td>1.00E-07</td>
<td>1.00E-07</td>
<td>1.82E-07</td>
<td>3.75E-06</td>
</tr>
<tr>
<td>B</td>
<td>2.45E-07</td>
<td>1.25E-06</td>
<td>4.26E-07</td>
<td>-</td>
</tr>
<tr>
<td>Se</td>
<td>5.26E-07</td>
<td>4.26E-07</td>
<td>9.04E-07</td>
<td>1.05E-04</td>
</tr>
<tr>
<td>P</td>
<td>7.01E-05</td>
<td>6.03E-05</td>
<td>1.00E-03</td>
<td>-</td>
</tr>
<tr>
<td>Zn</td>
<td>3.11E-06</td>
<td>4.76E-06</td>
<td>1.88E-06</td>
<td>1.70E-05</td>
</tr>
</tbody>
</table>

The hazard quotient (HQ) for each metal is calculated as follows: $HQ = \frac{ADD}{RfD}$

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

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**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.

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