

Assessment of Heavy Metal Levels in Offal Meats (Kidney and Liver) of Beef Sold at Gwagwalada Market, Abuja, Nigeria

ABSTRACT

Aims: To determine the concentrations of heavy metals (Cd, Fe, Mn, Pb, and Zn) in kidney and liver of slaughtered cattle.

Study design: Analytical method

Place and Duration of Study: Samples obtained from Gwagwalada abattoir in Abuja, Nigeria and transported University of Abuja, Chemistry Laboratory for analysis. The study lasted for four (4) months.

Methodology: Wet digestion of samples followed by metal analysis using Accusys 211 Bulk Scientific Atomic Absorption Spectroscopy (AAS).

Results: The empirical results indicated that the mean levels or concentration of these heavy metals in kidney of cattle were $47.75 \pm 0.002 \mu\text{g/g}$ Zn, $279.5 \pm 0.084 \mu\text{g/g}$ Fe, $10.00 \pm 0.00 \mu\text{g/g}$ Mn, while Cd and Pb were not detected. The levels or concentration of heavy metals in the liver sample were $0.500 \pm 0.000025 \mu\text{g/g}$ Cd, $57.00 \pm 0.0001 \mu\text{g/g}$ Zn, $119.5 \pm 0.0016 \mu\text{g/g}$ Fe, $5.75 \pm 0.000025 \mu\text{g/g}$ Mn, Pb was not detected. The concentration of Fe and Mn were found to be high in kidney sample than the liver sample.

Conclusion: The evidence from this study revealed the safety of these investigated offal meats as the concentration of these metals in the kidney and liver sample were within the maximum permissible limit according to the European Commission (EC) and FAO/WHO standards.

Keywords: [AAS, Heavy Metals, Kidney, Liver, Nutrient, Offal]

1.0 INTRODUCTION

Although Nigeria is regarded as the 13th least meat consuming country in world, with approximately 1.4kg per capita unlike other countries like south Africa, Australia and US representing 10.7, 21.1 and 25.9 kilogram of beef and veal per capita [1], however this does mean that Nigeria is a large population of vegetarians, instead, it reflects a low standard of living. It is estimated that more than 2 billion people in the world are deficient in key vitamins and minerals, particularly vitamin A, iodine, iron and zinc. Deficiencies occur when people have limited access to micronutrient-rich foods such as meat, fish, fruit and vegetables. Most people with micronutrient deficiencies live-in low-income countries like Nigeria and are typically deficient in more than one micronutrient. Highly nutritious foods such as meat are particularly required for HIV/AIDS infected communities and also for women and children[2]. Specifically, beef is a great necessity in Nigeria and it is often considered as a very important delicacy of any menu, it is an insolence in Nigeria context to offer food to an adult guest without meat in the menu, hence, meat consumption is very high in the country especially among the urban dwellers.

In general, Offal meats also known as Organ meats are the eatable parts of an animal that are not skeletal muscle, these include rich melange of nutrient based animal organs such as Liver, kidney, pancreas, brain, heart, tongue, among others. They are meats primarily obtained from organically raised, grass-fed livestock which are reported to be highly rich in vitamin B1, B2, B6, folate, B12 and A, D, E and K [3]. Additionally, they are also found to contain sufficient minerals like phosphorus, iron, copper, magnesium, iodine, calcium, potassium, sodium, selenium, zinc and manganese needed by human body[4]. High quantities of essential fatty acids especially the arachidonic acid, the omega-3 fats EPA and DHA are

33 present in organ meats[4,5,6]. Organ meats are a staple part of Africa ancestors diets, supplying a significant nutritional
34 advantages to people with limited access to other nutrient dense foods [7].

35 It is perhaps the most nutrient dense food on the planet and contains specific bioavailable forms of nutrient complexes
36 (folate, choline and B12) that are very challenging to get elsewhere. Liver is one of the most popular meats and it is also
37 one of the most concentrated food sources of vitamin A (retinol)[8], methionine, selenium, iron and zinc that are critical for
38 healthy function. Raw liver can be frozen for 14 days to kill any parasites or pathogens and then grated into mashed
39 vegetables, such as cauliflower, or into scrambled eggs, soups and stews. It can also be ground in a food processor, and
40 cooked into meatloaf, burger patties, or into a dairy-free pate served on cucumber slices. Liver was often given to sick
41 people, as the huge amounts of quality nutrients in this organ helped rebuild their bodies.

42 Kidney is also highly nutrient dense and very concentrated form of protein with the full array of amino acids. The most
43 readily available kidneys are gotten from beef and lamb. It is highly rich in vitamin B12, selenium, iron, copper,
44 phosphorus and zinc [9]. It is usually gotten with the long strip of fat still in the centre, if this is from grass-fed beef or lamb
45 that fat has a good amount of both saturated and omega 3 fatty acids. This is extremely healthy and anti-inflammatory.
46 Most say that beef kidney is the mildest in flavour and is one of the best to start with [7].

47 **1.1 Toxicity of Heavy metals in Offal meat**

48 Side by side with these known benefits of including meat and meat products in the diet are problems associated with
49 excessive intakes of saturated fats, risks of food poisoning from improperly processed products, residues of chemicals
50 used in agriculture and animal production and other potentially adverse aspects[10].

51 A number of epidemiological studies have reported a direct relationship between the intake of animal protein and
52 predisposition to cancers at various sites -pancreas, breast, colon, prostate and endometrium - but there are many
53 contradictory reports. A summary of eleven case-controlled studies of colon cancer, three of stomach cancer and one of
54 breast cancer concluded that the available data do not provide convincing evidence that removal of meat from the diet
55 would substantially reduce the cancer risk [11,12].

56 Polycyclic hydrocarbon, (3,4-benzpyrene) is a carcinogen found a product gas of pyrolyzing organic material. This
57 carcinogen is reportedly formed on the surface of barbecued and grilled and smoked meat and fish products [10]. The
58 major source of this toxic compound is the flame itself, especially from charcoal. Several reports have indicated other toxic
59 metals (especially heavy metals family) that threatens the consumption of offal meats, the poisoning is associated with
60 several anthropogenic factors that contaminates the biotic and abiotic environment of the grazing animals. Heavy metals
61 occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are
62 regarded as trace (<1000 mg kg⁻¹) and rarely toxic [13,14]. Due to the disturbance and acceleration of nature's slowly
63 occurring geochemical cycle of metals by man, most soils of rural and urban environments may accumulate one or more
64 of the heavy metals above defined background values high enough to cause risks to human health, plants, animals,
65 ecosystems, or other media [15]through many processes such as the application of certain phosphatic fertilizers which
66 inadvertently adds Cd and other potentially toxic elements to the soil, including F, Hg, and Pb [16], pesticides, biosolids
67 and manures, municipal and industrial wastewater, Mining and milling of metal ores, stack or duct emissions of air, gas, or
68 vapor streams, and fugitive emissions such as dust from storage areas or waste piles (These metals will convert to oxides
69 and condense as fine particulates unless a reducing atmosphere is maintained [17]. The most common heavy metals
70 found at contaminated sites, in order of abundance are Pb, Cr, As, Zn, Cd, Cu, and Hg [18].

71 It is pertinent to state here that in very small amounts, some of these metals are necessary to support life but in larger
72 levels, they become toxic. They may build up in biological systems and become a significant health hazard [19].

73 Over 200,000 persons die annually due to food poison in Nigeria annually, these deaths were caused by contaminated
74 meat and food products through improper processing, preservation and service [20]. The risk of heavy metal
75 contamination in meat is of great concern for both food safety and human health because of the toxic nature of these
76 metals at relatively minute concentrations [21].

77 In Nigeria, beef is the most readily available and widely consumed meat [22]. The main source of metals in beef arises
78 from the feed contaminations as explained above, vehicular emissions and unhygienic slaughter places. It is on this
79 premises this study was carried out to assess the levels of some heavy metals (Cd, Fe, Mn, Pb and Zn) in liver and kidney
80 of beef sold at Gwagwalada abattoir, Gwagwalada, Abuja.

2. MATERIAL AND METHODS

2.1 Study Area

The present study was carried out in Gwagwalada, which is the commercial hub of Abuja, Nigeria. Gwagwalada is one of the six Local Government Area Councils of the Federal Capital Territory of Nigeria with an estimated population of 300,000. It houses the University of Abuja, several private companies bus stops, University teaching hospital, commodities open market, among others. It is located within longitude and latitude 8.9393N and 7.0787E respectively[21].

2.2 Sample Collection

Liver and kidney samples were bought at the Gwagwalada abattoir on a market day. All collected samples were stored in clean dry polythene bags and labelled correctly, after which they were brought immediately to the laboratory for preparation and treatment. Information on the grazing location, age and gender of the slaughtered cow were not known because the butcher men were semi-literate.

2.3 Sample Preparation and Pretreatment

The meat samples were rinsed with distilled water to remove any sand particles or any large size contaminants. The samples were thereafter cut into small pieces using clean ceramic knife and oven-dried at 100 °C. After drying, the samples were grounded into a fine powder using a ceramic mortar and stored in well-labeled sample bottles until used for acid digestion.

2.4 Acid digestion of samples

AOAC (1995) method and procedures were adopted. Acid mixture (10 mL, 70% high purity HNO₃ and 65% HClO₄, 4:1 v/v) was added to the 2g dry sample [23]. The wet digestion of the mixture was carried out at 80 °C to obtain a transparent solution. After cooling, the digested samples were filtered using Whatman no. 42 filter paper and the filtrate was diluted to 50 mL with deionised water. In triplicate, the level of heavy metals (Cd, Fe, Mn, Pb and Zn) were analysed in the filtrate of liver and kidney using atomic absorption spectrophotometer (Shimadzu Model 6800 with graphite furnace Model GFA 7000, Hydride unit was used for determination of mercury).

2.5 Statistical analysis

Data collected were presented as mean and standard deviation and were subjected to one-way analysis of variance (ANOVA) ($p=0.05$) to assess the influence of different variables on the concentrations of heavy metals in the offal meat tested. All statistical calculations were performed with SPSS 9.0 for windows[24].

3. RESULTS AND DISCUSSION

The mean values \pm standard deviation of iron, manganese, copper, zinc, lead, cadmium and mercury concentrations in the studied liver and kidney are given in Table 1. The concentrations of heavy elements in the selected studied species are varied quietly such as, Fe (44.87–250.23), Mn (7.72–13.99), Cu (2.3–12.05), Zn (16.79–49.43), Pb (3.24–9.17), Cd (1.17–4.25) and Hg (0.014–0.055 $\mu\text{g/g}$ dry wt.).

Table 1: Concentrations of heavy metals in liver and kidney samples obtained from an abattoir in Gwagwalada, Abuja.

Metals	Concentration of metals ($\mu\text{g/g}$)	
	Kidney	Liver
Cd	Nd	0.50 \pm 0.00
Pb	Nd	N.D
Zn	47.75 \pm 0.002	57.00 \pm 0.0001
Fe	279.5 \pm 0.084	119.5 \pm 0.0016
Mn	10.00 \pm 0.00	5.75 \pm 0.000025

The mean values \pm standard deviation of the concentrations of the metals in the livers and kidneys of the samples expressed in dry weight are presented in the table 1. The concentrations of these metals in liver and kidney samples

120 differed for each metal. The highest concentrations of Cd (0.5 ± 0.00) were detected in liver samples while highest
121 concentrations of Fe (279.5 ± 0.084) and Mn (10.00 ± 0.00) were detected in in Kidney samples.

122 Fe is the most abundant of all the metals studied while Pb was not detected in the liver and kidney samples. The mean
123 concentrations of Cd, Fe and Mn are more in the kidney than in the liver, this depicts lesser accumulation of heavy metals
124 in the cow liver. Nevertheless, the opposite is found as the level of Cd (0.50 ± 0.00) in the liver is more than that of kidney.
125 The order of the levels of these metals in the offal meat is thus: Fe > Zn > Mn > Cd > Pb.

126

127 Table 2: Concentrations of Cd and Pb in liver and kidney samples of the present study and compared with permissible
128 limits of European Commission (EC) and Food and Agriculture Organization/ World Health Organization (FAO/WHO) for
129 offal meats.

Kidney	Element in $\mu\text{g/g}$		Standard reference	
	Cadmium (Cd)	Lead (Pb)		
	Liver	Kidney	Liver	
0.1	0.1 -0.5	0.1	0.1 -0.5	FAO/WHO [25]
0.5	0.5	0.5	0.05	EC [26]
Nd	0.50	Nd	nd	Maximum limit for present study

130 nd- not detected.

131 European Commission (EU) and Food and Agriculture Organization/World Health Organization (FAO/WHO) metals
132 permissible limits in offal meats were compared with the concentrations of these metals found in the present study as
133 indicated in the table 2.

134 The present study did not exceed the international standard permissible limits of Cadmium which ranged from 0.1 -
135 $0.5\mu\text{g/g}$ while Lead was of no consequential effect as it was not detected at all.

136

137 4. DISCUSSION

138 Cadmium

139 Cadmium was not detected in the kidney sample while $0.50\pm 0.00\mu\text{g/g}$ represents the level in liver sample. The obtained
140 Cd concentration in Liver is within the EC and FAO limits of 0.1mg/kg [2]. Animals exposed to cadmium ingest it into their
141 livers add kidney as their protein-thiol group content leads to a strong fixation of heavy metals. Despite the excretory
142 mechanism for such metals, which is based on low molecular compounds with -SH groups, vertebrates could not develop
143 these mechanisms during the period of evolution to the extent necessary for today's anthropogenic sources of pollution
144 [27]. The herbivores of terrestrial fauna, birds as well as mammals, demonstrate generally higher renal cadmium than
145 carnivores since vegetation is contaminated by aerial deposition or by absorption of cadmium from the soil [28]. According
146 to the data obtained by Akan et al (2010)[29], the cadmium levels obtained in the livers and kidneys of cattle from
147 Maiduguri were $0.22\pm 0.02\mu\text{g/g}$ and $0.17\pm 0.04\mu\text{g/g}$ respectively. Iwegbue et al (2008)[30] in his studies also reported
148 $0.08\pm 0.24\text{mg/kg}$ and $0.14\pm 0.11\text{mg/kg}$ while Ambushe et al (2012) observed $62.6\pm 4.6\text{ng/g}$ and $508\pm 17\text{ng/g}$ for cadmium
149 levels in liver and kidney respectively. The result obtained is not in agreement with Sedkil et al (2003) [31] who reported
150 highest concentrations of Cd detected in kidneys and livers samples (10.3 and $5.1\mu\text{g/g}$ respectively). High accumulation of
151 Cd and its long half-life may induce diseases in humans, including osteoporosis and decrease of heart contraction ability,
152 especially in smokers consuming higher levels of Cd in offal meat products[32]. Cd may also cause disorders by inducing
153 secondary hyper-thyroidism, showing an antagonistic effect on the accumulation of Cu, Zn, Se and other elements,
154 disturbing reproductive processes and inducing neoplastic diseases[32].

155 Iron

156 The liver and kidney have higher concentrations (119 ± 0.0016 and $279.5\pm 0.084\mu\text{g/g}$ respectively) of Iron which are
157 comparatively higher than the mean levels of $125.2 - 146.8 \text{ mg/kg}$ reported for liver of cattle from 3 region of Slovakia[33].
158 Data obtained from Iwegbue et al (2008) [30] showed low mean levels of $37.75\pm 20.18\text{mg/kg}$ and $2.26\pm 17.80\text{mg/kg}$.

159 Iron is an important mineral that assists in the maintenance of basic life functions. It combines with protein and copper to
160 make haemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It
161 also aids in the formation of myoglobin, which supplies oxygen to muscle tissues [34]. Without sufficient iron, the body
162 cannot produce enough haemoglobin or myoglobin to sustain life. Despite the fact that iron is the fourth most abundant
163 metal in the earth's crust, iron deficiency is the world's most common cause of anaemia. The NAS DRI for children 4- to 8-
164 years-old is 10 mg/day [35].

165 Manganese

166 From Table 1, the mean Mn levels in Kidney and Liver are 10 μ g/g and 5.75 \pm 0.000025 μ g/g respectively. The
167 concentration of Mn in kidney is significantly higher than that of liver, this agrees with Akan et al (2010) that reported
168 1.34 \pm 0.22 μ g/g and 1.04 \pm 0.04 μ g/g for liver and kidney respectively in Maiduguri. Mean values of Mn observed by Iwegbue
169 et al (2008)[30] 11.32 \pm 6.05mg/kg and 9.67 \pm 5.34mg/kg for liver and kidney respectively are comparatively low to the data
170 obtained in this present study. A study by Ambushe et al (2012)[32] indicated 6800 \pm 660 and 3040 \pm 100 μ g/g Mn levels in
171 Liver and Kidney of Bovine meat which showed a relatively higher of Mn than the present study.

172 Manganese is an essential trace element and is required by the body to break down amino acids and produce energy.
173 Manganese can enter the body via ingestion, but most manganese is excreted in faeces—only 3 to 5 percent of
174 manganese is absorbed by the body when ingested [36]. Typically, people have small amounts of manganese in their
175 bodies. Under normal circumstances, the amount is regulated so the body has neither too much nor too little [37]. For
176 example, if large amounts of manganese are consumed, large amounts will be excreted. The Food and Nutrition Board of
177 the National Research Council reported that 2 to 5 mg of manganese/day is an "estimated safe and adequate daily dietary
178 intake" [37]. The World Health Organization (WHO) added that 2 to 3 mg/day is "adequate" and 8 to 9 mg/day is "perfectly
179 safe" [38]. Based on these studies, EPA has recommended that an appropriate The Oral Reference Dose (RfD) according
180 to EPA for manganese in food is 10 mg/day, which is calculated to a NOAEL of 0.14 mg/kg/day, where NOAEL represent
181 less serious of manganese exposure while LOAEL means a risky exposure. The estimated exposure dose for a child
182 ingesting on-site game (9.8 \times 10⁻² mg/kg/day) is below this NOAEL. Further, only a small amount of manganese is
183 absorbed, and a homeostatic mechanism regulates the amount in the body[39].

184 Lead

185 Lead was not detected in the liver and kidney samples which confirms these offal meats free from lead accumulation or
186 poisoning. The standard safe limit of lead by European Commission (EC 2001) [26] and FAO (1983) [25] are 0.4mg/kg
187 and 0.5mg/kg respectively. Lead has great potential to impair juvenile cognitive development and intellectual performance
188 and raises the risk of high blood pressure and cardiovascular diseases among adults.

190 Zinc

191 The obtained results showed that the zinc contents of liver and kidney samples were 57.00 \pm 0.0001 μ g/g and
192 47.75 \pm 0.002 μ g/g. the zinc concentration is lower in Kidney than in the Liver. According to Barki and Piscac (1981) [40],
193 the normal concentrations of zinc in meat samples are 35-45mg/D, Salisbury and Chan (1991)[40] also investigated Zn
194 concentrations in kidney and liver which ranged from 23 to 147.2 ppm. Zinc is an essential micronutrient in human diet,
195 required improve children's immunity to infections. Deficiency of Zn in adult can results in anaemia, dysfunctional motor
196 function and appetite disorder, etc while too much of Zn is also harmful to human health[41]. The concentrations of zinc in
197 all the samples studied were below the permissible limit 150 ppm and 100 μ g/g set by (ANZFA, 2001) and WHO/FAO
198 respectively[42,43].

200 CONCLUSION

201 According to FAO [44], to effectively combat malnutrition and under-nourishment in developing countries like Nigeria, 20g
202 of animal protein per person per day or 7.3 kg per year should be provided. This can be achieved by an annual
203 consumption of 33 kg lean meat or 45 kg fish or 60 kg eggs or 230 kg milk, respectively. These sources are usually
204 combined in the daily food intake, but in regions where not all of them are readily available, intake of the others needs to
205 be increased. Nutrients from animals may be of higher quality or more readily absorbed than vegetable sources.

206 However, these meat products must be free from heavy metals contamination. The results obtained in this study, showed
207 the concentrations of heavy metals (Cd, Pb, Zn, Fe, and Mn) in the liver and kidney of cattle sold in Gwagwalada abattoir
208 were within the international statutory safe limits. The none detection of Pb concentration in both sample of liver and
209 kidney implied that grazing area of the ruminant is free from contamination, which is advantageous both to animals and
210 man. The data obtained is therefore useful in supplementing existing food composition data, estimating dietary intakes of
211 heavy metals and framing food standards in Nigeria. However, a frequent quality assurance check should be carried out
212 only on liver and kidney but all offal meats sold across all abattoirs within the country to ensure that safe only meats are
213 sold.

214 **COMPETING INTERESTS DISCLAIMER:**

217 Authors have declared that no competing interests exist. The products used for this research are commonly and
218 predominantly use products in our area of research and country. There is absolutely no conflict of interest between the
219 authors and producers of the products because we do not intend to use these products as an avenue for any litigation but
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221 personal efforts of the authors.

222 **ETHICAL APPROVAL**

223 All authors hereby declare that "principles of laboratory animal care" (NIH publication no. 85-23, revised 1985) were
224 followed, as well as specific national laws where applicable. All experiments have been examined and approved by the
225 appropriate ethics committee"

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