Journal of Environment Pollution and Human Health, 2014, Vol. 2, No. 3, 69-73
Available online at http://pubs.sciepub.com/jephh/2/3/3

DOI:10.12691/jephh-2-3-3

Health Risk Posed by Lead, Copper and Iron via Consumption of Organ Meats in Kampala City (Uganda)

Patrick Ogwok[1,*], Michael Bamuwamye[2], Grace Apili[1], Juliet Hatoho Musalima[1]

[1]Department of Food Technology, Faculty of Science, Kyambogo University, Kyambogo, Kampala, Uganda
[2]Ministry of Health, Natural Chemotherapeutics Research Institute (NCRI), Kampala, Uganda
Corresponding author: ogwokp@yahoo.com

Received July 29, 2014; Revised August 11, 2014; Accepted August 28, 2014

Abstract Organ meat is a good source of protein, and some organs, notably the liver and kidney, are rich in vital minerals. In less developed countries, it is highly consumed because of tradition and being inexpensive. However, organ meats may contain high levels of heavy metals. The major objective of this study was to assess the level of risk posed to consumers by lead (Pb), copper (Cu) and iron (Fe) via the consumption of organ meats in Kampala City. Beef, goat and chicken liver, kidney, rumen, intestine, and chicken gizzard from five major markets in Kampala were assessed for levels of Pb, Cu and Fe. The heavy metal content was determined by flame and furnace atomic absorption spectrophotometry. Target Hazard Quotient (THQ) was used in health risk assessment to determine carcinogenicity of the samples. The concentration of heavy metals ranged from 0.04 to 1.11 mg/kg for lead; 3.5 x 10-4 to 0.66 mg/kg for copper, and 26.20 to 41.00 mg/kg for iron. The level of lead in the liver, kidney, rumen, intestine and gizzard was higher than the maximum recommended limit (0.5 mg/kg wet weight) according to EFSA. A health risk analysis based on the THQ yielded a value >1 for lead in beef and goat liver and kidney, and goat intestine, and 0.99 in chicken liver. This suggests that consumers would possibly experience significant risk from the consumption of lead through these organs. Regular consumption of offal in Kampala may therefore cause deleterious effects during a lifetime in humans most especially for children and women of child bearing age.

Keywords: *Animal offal, health risk, heavy metal*

Cite This Article: Patrick Ogwok, Michael Bamuwamye, Grace Apili, and Juliet Hatoho Musalima, "Health Risk Posed by Lead, Copper and Iron via Consumption of Organ Meats in Kampala City (Uganda)." *Journal of Environment Pollution and Human Health*, vol. 2, no. 3 (2014): 69-73. doi: 10.12691/jephh-2-3-3.

1. Introduction

Food contains a wide range of metallic elements including iron, selenium, copper and zinc required for maintenance of cellular processes in the human body. In contrast, lead, mercury, cadmium and arsenic play no useful role and pose a risk for human health when consumed. These elements are transferred through the food chain and accumulate in animal tissues, mainly in the liver, kidney and bones [1]. According to Miranda *et al.* [2], kidney may accumulate substantial amounts of heavy metals followed by liver. Liver is a storage organ and detoxifier. The kidney functions as a filter in the bodies of animals while the gizzard aids in digestion by grinding food in birds. High lead concentration in food is associated with cardiovascular, renal, nervous and skeletal-system diseases [3,4,5]. In addition, Pb is teratogenic, that is, it is associated with the development of abnormalities in babies when consumed during pregnancy [6].

The essential metals copper (Cu) and iron (Fe) are of highly interactive nature with lead (Pb) and the latter may induce changes in their metabolism [7]. A study in rats showed that low dietary Cu enhanced absorption of lead in rats fed on a diet containing 5000 mg/kg of Cu [8]. Similar findings were obtained for iron. As a result, copper and iron are metabolically interrelated and play a role in the toxicology of dietary lead. At low levels of dietary lead, increased levels of dietary iron and copper have been reported to reduce lead absorption [8]. However, only when both copper and iron are at optimal levels in the diet is the effect of lead on iron metabolism completely inhibited. In young children, Pb exposure has been associated with decreased biosynthesis of the hormonal metabolite of vitamin D (1, 25-dihydroxy-vitamin D) that is responsible for the metabolism of calcium [9]. Lead also has a strong effect on haeme biosynthesis and erythropoiesis.

Rapid and unorganized urban and industrial developments have been demonstrated to cause elevated levels of heavy metals in the environment [10,11,12]. As such, the rapid growth in urbanization in Uganda could have led to notable pollution in the environment. Vegetables and fish around Kampala district and along Kampala-Jinja highway have been reported to contain sizeable amounts of heavy metals [10,13]. There is however hardly any information on the heavy metal content of organ meats (liver, kidneys, heart, and lungs, rumen and intestines) although they are sold and consumed as a valuable food source in Uganda. Hence, little is known of the health risk associated with their consumption. The risk of heavy metal contamination in lean and organ meats is of great concern from both the food safety and public health perspective because of their toxicity at relatively minute concentrations [14]. This study therefore sought to assess the level of risk posed to the population by Pb, Cu and Fe via the consumption of organ meats from animals and birds.

2. Materials and Methods

2.1. Sampling

Raw liver, kidney, rumen, intestine and gizzard were obtained from five major markets in Kampala city. For every organ meat, two samples were obtained from each market. Ten samples were used for every organ meat. Organs were cut into small pieces and blended. The blended samples were packed separately in plastic bags and kept under frozen conditions overnight prior to analysis.

2.2. Apparatus Preparation

Heavy metal determination was done on a Shimadzu Electro-thermal Graphite Furnace atomic absorption spectrophotometer (GF-AAS) equipped with High-speed Deuterium (BGC-D2) and Self-Reversal method background correction (BGC-SR) along with an ASC-6100 auto-sampler (Shimadzu Corporation, Japan). Crucibles were soaked in nitric acid (10%) for 2 hours to remove contaminants, and then rinsed with distilled water to remove traces of nitric acid and contaminants. They were then dried in a muffle furnace for 1 hour at 550°C. The crucibles were held in the furnace until the temperature dropped to 250°C and transferred to a desiccator with porcelain plate using a pair of tongs where they were cooled to room temperature.

2.3. Determination of Heavy Metals

The amount of heavy metals in various internal organs was determined on a Shimadzu AA-6300 atomic absorption spectrophotometer according to Method 942.015 [15]. Samples (10 g) were weighed and pre-dried at 150°C in a muffle furnace for 1 hour to allow carbonization. The temperature was then increased to 250°C and 550°C after 1 hour and 2 hours respectively in order to minimize volatilization of lead. The muffle furnace was then turned off after 1 day and opened when the temperature dropped to 250°C. The ash was dissolved in 5 ml of 10% nitric acid with warming to ensure total dissolution and the mixture filtered through an acid washed filter paper into a 25 ml volumetric flask. The solution was then diluted to the mark of the volumetric flask with distilled water. Heavy metals were determined at wave lengths 283.3 nm, 324.8 nm, and 248.3 nm for Pb, Cu and Fe, respectively. The Absorbance was separately read off for specific metal.

2.4. Risk Assessment

A food intake study involving 50 respondents was done using a semi quantitative food frequency questionnaire in order to establish consumption patterns of consumers of organ meats. A health risk assessment based on Target Hazard Quotient (THQ) was done by combining laboratory, and consumption data [16,17]. Exposure to multiple pollutants results in additive and or interactive effects. Therefore, THQ values were calculated for Pb, Cu and Fe, and the total THQ (tTHQ) obtained as the arithmetic sum of the individual metal THQs for each internal organ. A tTHQ <1 means that the exposed population is assumed to be safe and 1 < tTHQ < 5 means that the exposed population is in a level of concern. The THQ for Pb, Cu and Fe was determined, according to the formula:

$$THQ = \left(\begin{matrix} EFr \text{ X } EDtot \\ \text{X } FIR \text{ X } C \end{matrix} \right) \text{X } 10^{-3} / \left(RfD \text{ X } BWa \text{ X } AT \right)$$

Where EFr is exposure frequency (365 days/year); EDtot is the exposure duration 58.65 years, average lifetime for Uganda; FIR is food ingestion rate (g/day); C is the heavy metal concentration in internal organ (µg/g); RfD is the oral reference dose (µg/g/day) (Table 1); BWa is the adult body average weight (60 kg); AT is the average time for non-carcinogens (equal to EFr X EDtot).

Table 1. Oral reference doses of heavy metals

Heavy metal	Pb	Cu	Fe
Oral reference dose, RfD ($mgKg^{-1}day^{-1}$)	0.004	0.04	0.700

Source: Harmanescu *et al.* [18].

2.5. Statistical Analysis

Data collected was analyzed using SPSS statistical package (SPSS Inc., Chicago, IL, USA). Analysis of variance, ANOVA, was performed to compare the level of heavy metals between the organ meats. Difference between means was obtained using the least significance difference (LSD) at $p < 0.05$.

3. Results and Discussion

3.1. Lead Concentration

The levels of Pb in the organ meats ranged from below limit of detection (< 0.001 mg/kg) to 1.11 mg/kg (Table 2). Lead was in the range of 0.56 to 1.11 mg/kg in the liver, 0.38 to 0.96 mg/kg in the kidney, < 0.001 to 0.09 mg/kg in the rumen, < 0.001 to 0.07 mg/kg in the intestines and 0.27 mg/kg in the gizzard. Beef liver had the highest concentration of Pb (1.11 mg/kg) and beef intestine had the lowest (< 0.001 mg/kg). There was no significant difference ($p<0.05$) between the amounts of Pb in liver from the different animals. Similarly, the amounts of Pb in the kidneys were not statistically different. Levels of Pb in the rumen of beef and goat were not different. Beef and goat intestines also had comparable levels of lead.

Lead is a cumulative poison which can trigger both acute and chronic symptoms of poisoning. Acute intoxications occur through consumption of large single doses of soluble lead salts while chronic intoxications can arise through regular consumption of foodstuffs contaminated with Pb. Children are particularly at risk of lead poisoning, both before and after birth, because they absorb lead more rapidly than adults. Neurologic problems in children are the principal concern of chronic lead exposure [19]. According to Parkin *et al.* (2010) [20], there is an observed increase in cancer cases, impaired neurological disorders, and malnutrition among children in Uganda. However, dietary contribution especially of contaminated meats and meat products as well as animal offal to these cancers remains unknown. The findings of this study show that the Pb content in all liver samples; beef kidney and goat intestine is above the recommended limits. Maximum levels (MLs) for Pb in offal of bovine animals, sheep, pig and poultry are set at 0.5 mg/kg wet weight in the European Commission Regulation (EC) Number 1881/2006 [21].

Table 2. Heavy metal concentration of Pb, Cu and Fe (μg/g) in the various internal organs

Organ meat	Lead	Copper	Iron
Cow liver	1.11^{a}±0.18	0.58^{a} ±0.03	41.00^{a} ±1.53
Goat liver	0.76^{a}±0.10	0.66^{a} ±0.03	40.05^{a} ±1.00
Chicken liver	0.56^{ab} ±0.03	< 0.002	40.75^{a} ±1.30
Cow kidney	0.96^{a} ±0.08	0.10^{b} ±0.02	39.60^{a} ±0.58
Goat kidney	0.38^{b} ±0.30	0.13^{b} ±0.00	39.10^{a} ±2.52
Cow rumen	<0.001	0.05^{c} ±0.00	38.65^{a} ±1.15
Goat rumen	0.09^{c} ±0.18	<0.002	37.40^{a} ±0.56
Cow intestines	0.07^{c} ±0.11	<0.002	39.00^{a} ±1.73
Goat intestines	<0.001	0.02^{c} ±0.00	26.20^{b} ±2.08
Chicken gizzard	0.27^{ab} ±0.23	0.12^{ab} ±0.00	40.70^{a} ±1.53

Values in columns followed by a different superscript letter are significantly different ($p < 0.05$).

3.2. Copper

The concentration of copper in the organs ranged from not detected (< 0.002 mg/kg) to 0.66 mg/kg. Copper was in the range of not detected to 0.66 mg/kg in the liver, 0.10 to 0.13 mg/kg in the kidney, not detected to 0.05 mg/kg in the rumen, not detected to 0.02 mg/kg in the intestines, and 0.12 mg/kg in the gizzard. Of all the organs, liver of the goat had the highest concentration of 0.66 mg/kg and beef intestine had the lowest concentration. There was no significant difference (p>0.05) between the levels of Cu in the beef and goat livers. Copper content in chicken liver was below limits of detection. There was no significant difference (p>0.05) between the amount of Cu in beef and goat kidneys. Goat rumen had Cu concentration below detection limits. Cu was detected in low amounts in beef rumen. Copper concentration was 0.02 mg/kg in the goat intestine but not detected in the beef intestine. Copper concentration was 0.12 mg/kg in the chicken gizzard. Although copper is widely distributed throughout the body, its concentration in tissues and organs vary among animals with the liver, brain, heart and kidneys containing the highest amounts [22].

The WHO permissible limit for copper in all foods is 40 mg/kg [23] while 100 mg/kg body weight is the lethal dose for humans [24]. Although limited information is available on chronic copper toxicity, toxic levels of copper can lead to Wilson's and Menke's diseases [25]. Copper concentration in the range 100 to 300 mg/kg is not a health risk [23] but levels below 10 mg/kg in muscle, and organs and other tissues of animals are suggestive of copper deficiency [26,27]. The results of this study therefore indicate that liver and kidney of beef and goat, and gizzard of chicken are deficient in Cu.

3.3. Iron

Levels of iron in the liver, kidney, rumen and intestines of beef and goat, and that in the liver and gizzard of chicken was low. The concentration of iron in the organs ranged from 26.20 to 41.00 mg/kg. Iron was in the range of 40.05 to 41.00 mg/kg in the liver, 39.10 to 39.60 mg/kg in the kidney, 37.40 to 38.65 mg/kg in the rumen, 26.20 to 39.00 mg/kg in the intestines and 40.70 mg/kg in the gizzard. Generally, there was no significant difference (p>0.05) between the amounts of Fe in organ meats except for the intestines. There was no significant difference (p>0.05) between Fe concentration in the liver of beef, goat and chicken. There was no significant difference (p>0.05) between the amount of Fe in beef and goat kidneys, and also no notable difference between the amount of Fe in goat and beef rumens. However, there was a significant difference (p>0.05) between the amount of Fe in goat and beef intestines.

Iron concentration in the range of 45 to 300 mg/kg and 30 to 150 mg/kg is categorized as adequate respectively in beef liver and beef kidney; while 30 to 40 mg/kg is marginal in poultry liver [27]. Besides, Demirezen and Uruc [28] reported a permissible limit of iron in food to be in the range of 30 to 150 mg/kg. Very high concentrations may lead to tissue damage, as a result of the formation of free radicals [23]. Our results show that the iron content of the studied internal organs is within range and therefore does not present any health risk in regular consumers.

3.4. Food Intake Study of the Internal Organs

A food intake study involving consumers of organ meats was carried out using a semi-quantitative food frequency questionnaire randomly administered to 50 respondents. A high proportion of people in Kampala were found to regularly consume organ meats. Liver, rumen and intestines were most consumed compared to other organs (Figure 1). Sixty seven per cent of the respondents consumed chicken gizzard. Goat liver as well as beef and goat kidneys were the least consumed (respectively 50%, 53% and 33% of the respondents) probably because they are less available when compared with other organs. A high proportion (80%) of people consumed only beef liver. The number of those who consumed only beef rumen and intestine was 80% of the studied population.

According to this study, an average consumer eats 300 g of animal offal in a single time. In general, the frequency of consumption was highest for beef and goat rumens and intestines, followed by beef liver. Thirty two per cent of the respondents consumed beef rumen and intestines at least once a day while 38% consumed it more than once a week. The percentage of respondents who consumed goat rumen and intestines at least once a day and more than once a week was evenly split at 29%. On the other hand, 38% and 17% respondents respectively consumed beef liver at least once a day, and more than once a week. The consumption of goat liver was also high with 26% of the respondents consuming it at least once a day. Chicken liver and gizzard were moderately consumed with higher consumers (respectively 31% and 36%) consuming them once a week.

3.5. Risk Analysis

The tTHQ ranged between 0.355 and 1.754 in the organ meats. THQ for individual metals were in general in the order Pb>Fe>Cu, respectively contributing >70%, 11%, and <7% of the total THQ in the most risky organs. This demonstrated relatively minor risk for Cu and Fe, and dominant contribution from lead for consumers in Kampala City. Of the three metals considered, the THQ for Pb was >1 in beef and goat liver, beef kidney and goat intestine, and 0.99 in chicken liver. This suggests therefore that regular consumption of these organs is likely to cause deleterious effect during a lifetime.

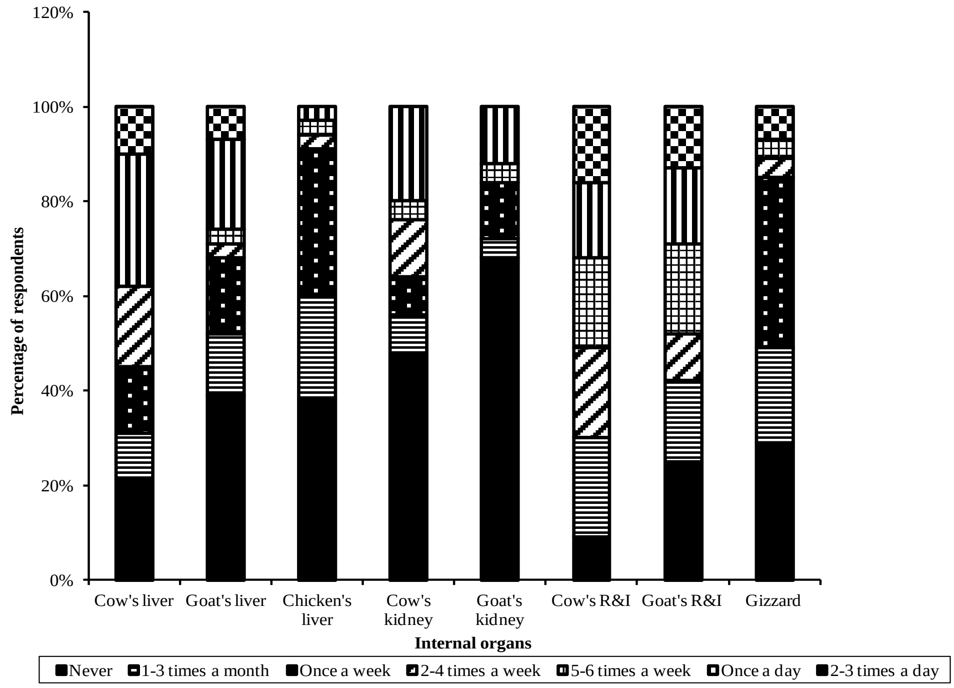

Figure 1. The proportions of people who consumed a particular internal organ

Table 3. THQs for lead, copper and iron in the various internal organs

Organ meats	THQ			tTHQ	THQ X 100 /tTHQ		
	Pb	Cu	Fe		Pb	Cu	Fe
Cow liver	1.39	0.07	0.29	1.75	79.13	4.16	16.70
Goat liver	0.95	0.08	0.29	1.32	72.02	6.29	21.68
Chicken liver	0.70	<0.01	0.29	0.99	70.64	NA	29.36
Cow kidney	1.20	0.01	0.28	1.50	80.21	0.87	18.92
Goat kidney	0.48	0.02	0.28	0.77	61.69	2.08	36.23
Cow rumen	0.11	0.01	0.28	0.40	28.61	1.52	69.87
Goat rumen	0.09	<0.01	0.27	0.36	24.79	NA	75.21
Cow intestines	0.05	<0.01	0.28	0.33	15.20	NA	84.80
Goat intestines	1.09	<0.01	0.18	1.27	85.60	0.24	14.16
Chicken gizzard	0.34	0.02	0.29	0.64	52.49	2.33	45.19

NA: Not applicable; tTHQ: Total Target Hazard Quotient

4. Conclusions

The health risk posed by exposure to lead, iron and copper through regular consumption of animal offal based on target hazard quotient was high with respect to lead. Therefore, beef, goat and chicken organ meats from Kampala markets may not be safe. The high lead content is indicative of high level of environmental pollution and therefore underlies that animal offal could be a biomarker of environmental pollution considering that animals are exposed to heavy metals through several environmental sources. Overall, the consumption of organ meats in Kampala could cause deleterious effects during a lifetime in humans especially for children and women of child bearing age.

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