Asian Journal of Physical and Chemical Sciences

7(2): 1-8, 2019; Article no.AJOPACS.51136
ISSN: 2456-7779

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

Adefarati Oloruntoba[1*] and Isaiah Adukwu Nathaniel[2]

[1]National Biotechnology Development Agency, Idofin-Isanlu, Nigeria.
[2]Department of Chemistry, University of Abuja, Abuja, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author AO designed the study, performed the lab and statistical analysis and wrote the first draft of the manuscript. Author IAN managed sample collection, partook in the lab analyses of the samples and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOPACS/2019/v7i230090
Editor(s):
(1) Dr. Natt Makul, Phranakhon Rajabhat University, Thailand.
Reviewers:
(1) Ahmed N. F. Neamat-Allah, Zagazig University, Egypt.
(2) Obioha Felix Chidiebere, University of Nigeria Nsukka, Nigeria.
Complete Peer review History: http://www.sdiarticle3.com/review-history/51136

Original Research Article

Received 11 June 2019
Accepted 20 August 2019
Published 26 August 2019

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±0.002 μg/g Zn, 279.5±0.084 μg/g Fe, 10.00±0.00μg/g Mn, while Cd and Pb were not detected. The levels or concentration of heavy metals in the liver sample were 0.500=±0.000025 μg/g Cd, 57.00±0.0001 μg/g Zn, 119.5±0.0016 μg/g Fe, 5.75±0.000025

**Corresponding author: E-mail: oloruntobaadefarati@gmail.com;*

μg/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. INTRODUCTION

Although Nigeria is regarded as the 13th least meat consuming country in world, with approximately 1.4 kg 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 arachidoic acid, the omega-3 fats EPA and DHA are present in organ meats [4,5,6]. Organ meats are a staple part of Africa ancestors diets, supplying a significant nutritional advantages to people with limited access to other nutrient dense foods [7].

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

Kidney is also highly nutrient dense and very concentrated form of protein with the full array of amino acids. The most readily available kidneys are gotten from beef and lamb. It is highly rich in vitamin B12, selenium, iron, copper, 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 that fat has a good amount of both saturated and omega 3 fatty acids. This is extremely healthy and anti-inflammatory. Most say that beef kidney is the mildest in flavour and is one of the best to start with [7].

1.1 Toxicity of Heavy Metals in Offal Meat

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

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

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

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

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

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

2. MATERIALS 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 2 g 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=.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 ± 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 µg/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 (µg/g)	
	Kidney	Liver
Cd	Nd	0.50±0.00
Pb	Nd	N.D
Zn	47.75±0.002	57.00±0.0001
Fe	279.5±0.084	119.5±0.0016
Mn	10.00±0.00	5.75±0.000025

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

Fe is the most abundant of all the metals studied while Pb was not detected in the liver and kidney samples. The mean concentrations of Cd, Fe and Mn are more in the kidney than in the liver, this depicts lesser accumulation of heavy metals 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. The order of the levels of these metals in the offal meat is thus: Fe > Zn > Mn > Cd > Pb.

Table 2. Concentrations of Cd and Pb in liver and kidney samples of the present study and compared with permissible limits of food and agriculture organization/ world health organization (FAO/WHO) and European commission (EC) for offal meats

Element in µg/g				
Cadmium (Cd)		Lead (Pb)		Standard reference
Kidney	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

nd- not detected

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

The present study did not exceed the international standard permissible limits of Cadmium which ranged from 0.1 -0.5 µg/g while Lead was of no consequential effect as it was not detected at all.

4. DISCUSSION

4.1 Cadmium

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

4.2 Iron

The liver and kidney have higher concentrations (119±0.0016 and 279.5±0.084 µg/g respectively) of Iron which are comparatively higher than the mean levels of 125.2 – 146.8 mg/kg reported for liver of cattle from 3 region of Slovakia [33]. Data obtained from Iwegbue et al. [30] showed low mean levels of 37.75±20.18 mg/kg and 2.26±17.80 mg/kg.

Iron is an important mineral that assists in the maintenance of basic life functions. It combines with protein and copper to make haemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues [34]. Without sufficient iron, the body cannot produce enough haemoglobin or myoglobin to sustain life. Despite the fact that iron is the fourth most abundant 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-years-old is 10 mg/day [35].

4.3 Manganese

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

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

4.4 Lead

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

4.5 Zinc

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

5. CONCLUSION

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

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

ETHICAL APPROVAL

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. OECD, Meat consumption (indicator); 2019.
   DOI: 10.1787/fa290fd0-en
   (Accessed on 05 April 2019)
2. Food and Agriculture Organization of the United Nations: Meat & Meat Products – Meat Consumption.
   Available:http://www.fao.org/ag/againfo/themes/en/meat/background.html
   (Retrieved 25 November 2014)
3. Pereira PMC, Vicente AFR. Meat nutritional composition and nutritive role in the human diet. Meat Science. 2013;93(3): 586-592.
4. Cordain L, Eaton SB, Miller JB, Mann N, Hill K. The paradoxical nature of hunter-gatherer diets: Meat-based, yet non-atherogenic. European Journal of Clinical Nutrition. 2002;56(S1):S42.
5. Park YW, Washington AC. Fatty acid composition of goat organ and muscle meat of alpine and Nubian breeds. Journal of Food Science. 1993;58:245-248.
6. Nicklas TA, Drewnowski A, O'Neil CE. The nutrient density approach to healthy eating: Challenges and opportunities. Public Health Nutr. 2014;1-11.
7. David Jockers. The many health benefits of eating organ meats.
   Available:http://dailyhealthpost.com/2014-03-18-the-many-health-benefits-of-eating-organ-meats/

[Retrieved May 10 2016]

8. The United States Department of Agriculture Agricultural Research Service. National Nutrient Database for Standard Reference Release 27.
[Accessed on September 29th, 2018]
9. Ling; Fish, Coked, dry heat: 9
Available:http://www.eatthismuch.com/food/view/beef-kidneys,3447/
[Accessed on September 29th, 2018]
10. Alrnoid Bender: Meat and meat products in human nutrition in developing countries. Food and Nutrition Paper 53, Food and Agriculture Organization of The United Nations Rome; 1992.
Available:http://www.fao.org/docrep/T0562E/T0562E00.HTM retrieved 04/11/1992
11. Phillips RL, Snowdon DA, Brin BH. Cancer in vegetarians. In "Environmental Aspects of Cancer. The role of the macro and micro components of foods". Ed Wynder EL, Leveille GA, Weisburger JH, Livingston GE. Food and Nutrition Press, Westport, CT; 1983.
12. Kritchevsky D. Meat and Cancer. In Pearson and Dutson. 1990;89-104.
Available:http://www.fao.org/docrep/T0562E/T0562E06.htm
13. Kabata-Pendias, Pendias H. Trace metals in soils and plants. CRC Press, Boca Raton, Fla, USA, 2nd edition; 2001.
14. Pierzynski GM, Sims JT, Vance GF. Soils and environmental quality. CRC Press, London, UK, 2nd edition; 2000.
15. D'Amore JJ, Al-Abed SR, Scheckel KG, Ryan JA. Methods for speciation of metals in soils: A review. Journal of Environmental Quality. View at Publisher. View at Google Scholar. View at PubMed. View at Scopus. 2005;34(5):1707–1745.
Available:http://www.hindawi.com/journals/isrn/2011/402647/ref/
16. Raven PH, Berg LR, Johnson GB. Environment, Saunders College Publishing, New York, NY, USA, 2nd edition; 1998.
Available:http://www.hindawi.com/journals/isrn/2011/402647/ref/
17. Smith LA, Means J, Chen LA, et al. Remedial options for metals-contaminated sites. Lewis Publishers, Boca Raton, Fla, USA; 1995.
18. USEPA, Report: Recent Developments for In Situ Treatment of Metals contaminated Soils, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response; 1996.
19. United States Department of Labour: Occupational Safety & Health Administration; 2014.
Available:https://www.osha.gov/SLTC/metalsheavy/
20. Santhi D, Balakrishnan Balakrishnan V, Kalaikannan A, Radhakrishnan KT. Presence of heavy metals in pork products in Chennai (India), American Journal of Food Technology. 2008;3:192-199.
21. Wikipedia Gwgagwalada.
Available:https://en.wikipedia.org/wiki/Gwagwalada
[Accessed 16 March 2019]
22. AOAC. Official methods of analysis. 16th Edition, Association of Official Analytical Chemists, Washington DC; 1995.
23. Udoh EJ, Akintola JO. An analysis of beef demand in a Nigerian urban city. Global Journal of Pure and Applied Sciences. 2002;9(1):7-12.
24. Ozdamar K. Biostatistics with SPSS. Kann Press Eskisehir. 1991;2-23.
Available:www.aun.edu.eg/journal_files/401_J_7465.pdf
25. Codex Alimentarius Commission. Joint FAO/WHO food standards programme. Codex Committee on Methods of analysis and sampling, twenty-eighthsession, Budapest, Hungary; 2007.
26. Commission of the European Communities. Commission Regulation (EC) No. 466/2001 of 8 March 2001 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Communities,L77. 2001;1–13.
27. Pompe-Gotal J, Crnic AP. Cadmium in tissue of roe deer (*Capreolus capreolus*) in Croatia. Vet. Arhiv. 2002;72:303-310.
28. Peterson PJ, Alloway BJ. Cadmium in soils and vegetation. In: The Chemistry, Biochemstry and Biology of Cadmium. (Webb. M., Ed.), Elsevier, North Holland Biomedical Press, Amsterdam, New York, Oxford 1974. 1979;45-92.
29. Akan JC, Abdulrahman FI, Sodipo OA, Chiroma YA. Distribution of heavy metalls in the liver, kidney and meat of beef, mutton, caprine and chicken from Kasuwan Shan Market in Maiduguri Metropolis, Borno State, Nigeria. Research Journal of Applied Sciences, Engineering and Technology. 2010;2(8):743-748.
30. Iwegbue CMA. Heavy metal composition of livers and kidneys of cattle from southern

Nigeria. Vet. Arhiv. Veterinarski Arhiv. 2008;78(5):401-410.
31. Sedki N, Lekouch S. Gamon, Pineau A. Sci. Total Environ. 2003;317:201–205.
32. Ambushe A, Mokgadi A, Hlongwane M, Robert I. McCrindle, Cheryl M. E. McCrindle. Assessment of levels of V, Cr, Mn, Sr, Cd, Pb and U in bovine meat: S. Afr. J. Chem. 2012;65:159-154.
33. Beata Korenekova, Magdalena Skalicka, Pavel Nad. Cncentration of some heavy metals in cattle reared in the vicinity of a metallurgic industry: Veterinarski Archiv. 2002;72(5):259-267.
34. [ANR] Austin Nutritional Research. Reference guide for minerals; 2003. Availablefrom:http://www.realtime.net/anr/minerals.html
35. [NAS] National Academy of Sciences. 2001. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington, DC: National Academy Press. Davidsson L, Cederblad A, Hagebo E, et al. Intrinsic and extrinsic labeling for studies of manganese absorption in humans. J Nutr. 1988;118: 1517–1524.
Cited in: Agency for Toxic Substances and Disease Registry. Toxicological profile for manganese. Atlanta: U.S. Department of Health and Human Services; 2000.
36. [EPA] U.S. Environmental Protection Agency. Health assessment document for manganese. Final draft. Cincinnati, OH: U.S. Environmental Protection Agency, Office of Research and Development. EPA-600/8-83-013F. Cited in: Agency for Toxic Substances and Disease Registry. 2000. Toxicological profile for manganese. Atlanta: U.S. Department of Health and Human Services; 1984.
37. [NRC] National Research Council. Recommended dietary allowances. 10th edition. Food and Nutrition Board, National Research Council. Washington, DC: National Academy Press. Cited in: U.S. Environmental Protection Agency. Integrated Risk Information System. Manganese (CASRN 7439-96-5). 1989; 230–235.
Available:http://www.epa.gov/iris/subst/0373.htm
38. [WHO] World Health Organization. Trace elements in human nutrition: Manganese. Report of a WHO expert committee. Geneva, Switzerland: Technical Report Service, 532, WHO. p. 34–36. Cited in: U.S. Environmental Protection Agency. Integrated risk information system. Manganese (CASRN). 1973;7439:96-5.
Available:http://www.epa.gov/iris/subst/0373.htm
39. Bartik M, Piscac A. A veterinary toxicology. Elsevier, New York; 1981.
Available:http://www.sciencedirect.com/science/article/pii/S1687428512000040
40. Salisbury CDC, Chan W. Multielement concentrations in liver and kidney tissues from live species of Canadian slaughetred animals. Journal of the Association of Analytical Chemistry. 1991;74:587-591.
Available:http://www.sciencedirect.com/science/article/pii/S1687428512000040
41. ATSDR. Agency for toxic substances and diseases registry, Division of Toxicology. Clifon Road, NE, Atlanta, GA; 2004.
Available:http://www.atsdr.cdc.gov/toxprofiles/
42. ANZFA (Australia New Zealand Food Authority). Wellington NZ 6036; 2001.
43. Meat Consumption: Animal Production and Health. Food and Agriculture Organization of the United Nations.
Available:http://www.fao.org/ag/againfo/themes/en/meat/background.html
[Retrieved May 2016]
44. Meat consumption.
Available:http://www.fao.org/ag/againfo/themes/en/meat/background.html

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/51136