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Distribution of Heavy Metals in the Liver, Kidney and Meat of Beef, Mutton, Caprine and Chicken from Kasuwan Shanu Market in Maiduguri Metropolis, Borno State, Nigeria

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Abstract: This study was to determine the concentrations of heavy metals (Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd, As, Ni and Pb) in liver, kidney and meat of beef (cow), mutton (sheep), caprine (goat) and chicken, from Kasuwan Shanu Market in Maiduguri Metropolis, Borno State, Nigeria by using Perkin-Elmer Analyst 300 Atomic Absorption Spectroscopy (AAS). The levels of heavy metals in the liver, kidney and meat of beef, mutton, caprine and chicken ranged from 0.23 to 1.22±0.21 μg/g Cr; 0.1 to 1.34±0.23 μg/g Pb; 0.10 to 1.44±0.06 μg/g Cu; 0.98 to 4.65±0.30μg/g Fe; 0.01 to 1.09±0.26 μg/g Ni; 0.45 to 4.11±0.44 μg/g Mn; 0.07 to 0.76±0.15μg/g Cd; 0.01 to 0.34±0.23μg/g As and 1.10 to 6.23±0.16 μg/g Zn. The concentrations of all the metals in the liver, kidney and meat of beef, mutton, caprine and chicken were found to be statistically significant ($p<0.05$). Generally, livers and kidneys were found to have the highest significant levels of metals and meat the lowest levels. When compared to one another (beef, mutton, caprine and chicken), there did show significant differences. Hence, the concentrations of all the metals were within the tolerance limits with the exception of Cr and Pb, which were higher than standard limits.

Key words: Animals, distribution, heavy metals, liver, kidney, meat

INTRODUCTION

Toxic metal is defined as that metal, which is neither essential nor has beneficial effect, on the contrary, it displays severe toxicological symptoms at low levels and is defined as a metal with a specific weigh more than 5 g/cm^3. With increasing industrialization, more and more metals are entering into the environment. These metals stay permanently because they cannot be degraded in the environment. They enter into the food material and from there they ultimately make their passage into the tissue (Baykov *et al*., 1996). Lead, cadmium, mercury and arsenic are among the main toxic metals which accumulate in food chains and have a cumulative effect (Cunningham and Saigo, 1997). Heavy metals often have direct physiologically toxic effects and are stored or incorporated in living tissues (Baykov *et al*., 1996). A study carried out by John and Jeanne (1994) showed that levels of arsenic, cadmium, mercury and lead were detected in several tissues of goats; the results showed that the levels of the above metals were found to be very high and generally above the permissible level. Similarly, the distribution and localization of some heavy metals in the tissues of some calf organs were detected, the most affected organs, which showed higher levels of trace metals, were livers, kidneys and small intestines (Horky *et al*., 1998). Lead is a metabolic poison and a neurotoxin that binds to essential enzymes and several other cellular components and inactivates them (Cunningham and Saigo, 1997). Toxic effects of lead are seen on haemopoietic, nervous, gastrointestinal and renal systems (Baykov *et al*., 1996). Food is one of the principle environmental sources of cadmium (Baykov *et al*., 1996). As cadmium moves through the food chain it becomes more and more concentrated as it reaches the carnivores where it increases in concentration by a factor of approximately, 50 to 60 times (Daniel and Edward, 1995). Toxic effects of cadmium are kidney dysfunction, hypertension, hepatic injury and lung damage (John and Jeanne, 1994). Cadmium chloride at teratogenic dose induced significant alterations in the detoxification enzymes in the liver and the kidney (Reddy and Yellamma, 1996). Animals vary in their arsenic accumulation depending upon the type of food they consume (John and Jeanne, 1994). Acute arsenic exposure can give symptoms with rapid onset of headache, nausea and severe gastrointestinal irritation (Allan *et al*., 1995). Similarly, increase in levels of copper causes liver, kidney and brain damage, which may follow haemolytic crisis (Judith, 1994). Zinc concentrations were found to be

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highest in meat, liver, fish and eggs (Janet and Carl, 1994).

The risk associated with the exposure to heavy metals present in food product had aroused widespread concern in human health. Improvements in the food production and processing technology had increased the chances of contamination of food with various environmental pollutants, especially heavy metals. Ingestion of these contaminants by animals causes deposition of residues in meat. Due to the grazing of cattle on contaminated soil, higher levels of metals have been found in beef and mutton (Sabir *et al.*, 2003). Gonzalez-Waller *et al.* (2006) also recorded the levels of toxic metals (lead and cadmium) in meat product exceeding recommended limits.

Meat is a very rich and convenient source of nutrients including also to a large extent microelements. Chemical composition of meat depends on both the kind and degree of the feeding animal. The need for mineral compounds depends on the age, physiological state and feed intake as well as on living conditions (Baykov *et al.*, 1996). Contamination with heavy metals is a serious threat because of their toxicity, bioaccumulation and biomagnifications in the food chain (Demirezen and Uruc, 2006). Although contamination of animal feed by toxic metals cannot be entirely avoided given the prevalence of these pollutants in the environment, there is a clear need for such contamination to be minimized, with the aim of reducing both direct effects on animal health and indirect effects on human health (SCAN, 2003). Toxic effects of metals have been described in animals under relatively low levels of metal exposure (Kostial, 1986); one of the earliest effects is the disruption of trace element metabolism (Goyer, 1997; Lo´pez-Alonso *et al.*, 2002).

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 (Santhi *et al.*, 2008; Mahaffey, 1977). Instances of heavy metal contamination in meat products during processing have been reported (Santhi *et al.*, 2008; Brito *et al.*, 2005). In other cases, contaminated animal feed and rearing of livestock in proximity to polluted environment were reportedly responsible for heavy metal contamination in meat (Miranda *et al.*, 2005; Sabir *et al.*, 2003; Koréneková *et al.*, 2002).

In Nigeria, chicken meat, the liver, kidney and meat of goat, sheep and beef are a major source of protein to the population and are widely consumed. The main source of metals in chicken and turkey meat arises from contamination of poultry feed and drinking water. Meat is a food material, which is composed of mainly protein, fat and some important essential elements. It is essential for growth and maintenance of good health. Contamination is transferred to animals through direct sewage water and industrial effluent. Contamination of meat can also be caused by vehicle emission and from dirty slaughter places. This study is carried out to determine the levels of heavy metals in different organs (liver, Kidneys and meat) of beef, mutton, caprine and chicken obtained from Kasuwan Shanu Market, Maiduguri, Borno State, Nigeria.

MATERIAL AND METHODS

Sample collection: Fresh samples of liver, Kidneys and meat of beef (cow), mutton (sheep), caprine (goat) and chicken were collected from the Kasuwan Shanu Market in Maiduguri Metropolis, Borno State, Nigeria. The samples were collected in polyethylene bags and transported to the laboratory for analysis. The study was carried out between the periods of November 2009 to June, 2010

Sample preparation: The collected samples were decomposed by wet digestion method for the determination of various metals. A known quantity, 10 g of each sample (liver, kidney and meat) was introduced into the digestion flask. 20 mL of sulphuric acid was added into it. The digestion flask was heated for 30 min. After the flocculation was settled, the flask was heated on high flame. After digestion, hydrogen peroxide was added drop wise until a clear solution was obtained. The content of the flask was filtered into a 50 mL volumetric flash and made up to the mark with distilled water.

Elemental analysis of samples: Determination of Cu, Zn, Co, Mn, Mg, Fe, Cr, Cd As, Ni and Pb in soil and vegetable samples were made directly on each of the final solutions using Perkin-Elmer Analyst 300 Atomic Absorption Spectroscopy (AAS).

Statistical analyses: Data collected were presented as mean and standard deviation and were subjected to one-way analysis of variance (ANOVA) ($p<0.05$) to assess whether heavy metals varied significantly between animals. All statistical calculations were performed with SPSS 9.0 for Windows (Ozdamar, 1991).

RESULTS AND DISCUSSION

The concentrations of heavy metals in the liver of beef, mutton, caprine and chicken are presented in Table 1. Cr levels ranged between 0.43 ± 0.10 and 1.22 ± 0.21 µg/g; 0.16 ± 0.02 and 1.34 ± 0.23 µg/g Pb; 0.54 ± 0.04 and 1.44 ± 0.06 µg/g Cu; 2.13 ± 0.11 and 4.65 ± 0.30 µg/g Fe; 0.09 ± 0.01 and 1.09 ± 0.26 µg/g Ni; 0.22 ± 0.01 and 0.77 ± 0.17 µg/g Co; 1.34 ± 0.22 and 4.11 ± 0.44 µg/g Mn; 0.22 ± 0.02 and 0.76 ± 0.15 µg/g Cd; 0.03 ± 0.01 and 0.34 ± 0.23 µg/g as and 2.34 ± 0.08 and 6.23 ± 0.16 µg/g Zn. The level of heavy metals in the kidney of beef, mutton, caprine and chicken is as presented in Table 2. Cr concentrations range from 0.27 ± 0.04 to 0.85 ± 0.01 µg/g; 0.08 ± 0.05 to 1.22 ± 0.32

Table 1: Concentrations of heavy metals in liver of Beef, Mutton, Caprine and Chicken from Kasuwan Shanu, Maiduguri Metropolis, Nigeria

	Concentrations (μg/g)									
Samples	Cr	Pb	Cu	Fe	Ni	Co	Mn	Cd	As	Zn
Beef	0.43±0.10[a]	0.25±0.01[a]	0.87±0.12[a]	2.13±0.11[a]	0.29±0.04[a]	0.43±0.06[a]	1.34±0.22[a]	0.22±0.02[a]	0.08±0.01[a]	4.24±0.16[a]
Mutton	0.76±0.03[b]	0.16±0.02[b]	0.54±0.04[b]	3.76±0.22[b]	0.09±0.01[b]	0.77±0.17[b]	2.76±0.43[b]	0.76±0.15[b]	0.34±0.23[b]	2.34±0.08[b]
Caprine	1.22±0.21[c]	1.34±0.23[c]	1.02±0.21[c]	3.98±0.31[c]	0.19±0.02[c]	0.22±0.01[c]	3.22±0.65[c]	0.44±0.03[c]	0.15±0.06[c]	6.23±0.16[c]
Chicken	0.65±0.04[d]	0.22±0.02[d]	1.44±0.06[d]	4.65±0.30[d]	1.09±0.26[d]	0.33±0.01[d]	4.11±0.44[d]	0.27±0.10[d]	0.03±0.01[d]	3.11±0.25[d]

Within column, mean with different letters are statistically significant $p<0.05$

Table 2: Concentrations of heavy metals in Kidney of Beef, Mutton, Caprine and Chicken from Kasuwan Shanu, Maiduguri Metropolis, Nigeria

	Concentrations (μg/g)									
Samples	Cr	Pb	Cu	Fe	Ni	Co	Mn	Cd	As	Zn
Beef	0.32±0.05[a]	0.15±0.03[a]	0.54±0.01[a]	1.87±0.07[a]	0.16±0.02[a]	0.23±0.04[a]	1.04±0.01[a]	0.17±0.04[a]	0.14±0.01[a]	3.87±0.09[a]
Mutton	0.65±0.02[b]	0.08±0.05[b]	0.34±0.02[b]	3.07±0.13[b]	0.04±0.01[b]	0.56±0.05[b]	2.04±0.21[b]	0.34±0.10[b]	0.18±0.06[b]	1.76±0.02[b]
Caprine	0.85±0.01[c]	1.22±0.32[c]	0.62±0.06[c]	2.51±0.15[c]	0.13±0.08[c]	0.14±0.01[c]	2.88±0.12[c]	0.39±0.07[c]	0.05±0.22[c]	4.76±0.44[c]
Chicken	0.27±0.04[d]	0.16±0.06[a]	0.44±0.10[d]	3.54±0.23[d]	0.24±0.01[d]	0.17±0.02[d]	3.67±0.14[d]	0.16±0.01[a]	0.11±0.01[d]	2.23±0.17[d]

Within column, mean with different letters are statistically significant $p<0.05$

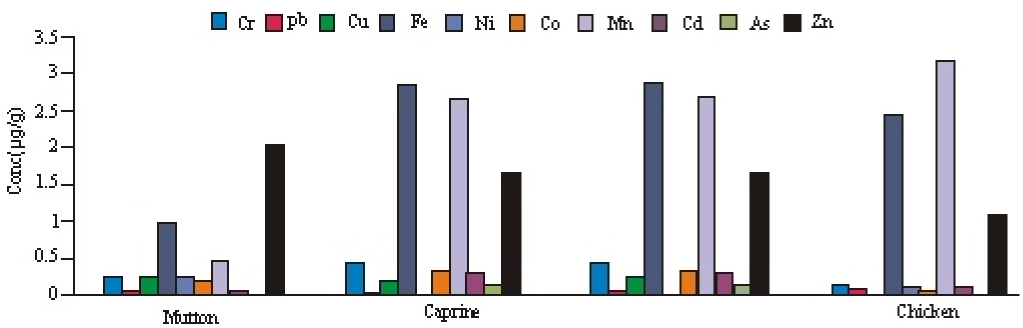

Fig. 1: Mean concentration of heavy metals in the Meat of Beef, Mutton, Caprine and Chicken from Kasuwan Shanu Maiduguri Metropolis, Nigeria

μg/g Pb; 0.34±0.02 to 0.62±0.06 μg/g Cu; 1.87±0.07 to 3.54±0.23 μg/g Fe; 0.04±0.01 to 0.24±0.01 μg/g Ni; 0.14±0.01 to 0.56±0.05 μg/g Co; 1.04±0.01 to 3.67±0.14 μg/g Mn; 0.16±0.01 to 0.39±0.07 μg/g Cd; 0.05±0.22 to 0.18±0.06 μg/g as and 1.76±0.02 to 4.76±0.44 μg/g Zn. The levels of heavy metals in the meat of beef, mutton, caprine and chicken are as presented in Fig. 1. Chromium concentrations range from 0.15 to 0.43 μg/g; 0.04 to 0.10 μg/g Pb; 0.01 to 0.24 μg/g Cu; 0.98 to 2.87 μg/g Fe; 0.01 to 0.22 μg/g Ni; 0.06 to 0.32 μg/g Co; 0.45 to 3.20 μg/g Mn; 0.070 to 0.29 μg/g Cd; 0.01 to 0.13 μg/g As and 0.10 to 2.04 μg/g Zn.

The concentrations of Chromium (Cr) were observed in the liver, kidney and meat of beef, mutton, caprine and chicken are as presented in Table 1, 2 and Fig. 1. The highest concentration of Cr was found in the liver of caprine (1.22±0.21 μg/g) and the lowest level was observed in meat of beef (0.23 μg/g). Cr is an essential element helping the body to use sugar, protein and fat, at the same time it is carcinogenic for organisms (Institute of Medicine, 2002). Excessive amounts of Cr may cause adverse health effects (ATSDR, 2004).The concentrations of all the metals in the liver samples studied were higher than the permissible limit of 0.10 μg/g.

Lead as observed in the liver of caprine showed the highest concentration of 1.34±0.23 μg/g and the lowest concentration of 0.1 μg/g in the meat of chicken. Similar results obtained by Spierenburg *et al.* (1988) who determined lead concentrations in liver and kidney of cattle within a 20 Km radius of zinc refineries and compared these with cattle in unpolluted control areas. Significantly higher amounts of lead in liver and kidneys were found in cattle sampled around the refineries than those cattle reared in the mining area and also higher than those in cattle in the rural area. Aranha (1994) reported higher concentration of lead than the permissible limit in the liver and kidney of animals. Danev *et al.* (1996) showed that 86% samples of liver and 100% samples of kidney were contaminated above the limits set by the country's regulations. Similarly, Maldonado *et al.* (1996) studied lead with reference to its intestinal absorption, mobilization and redistribution during lactation in rats and showed significantly higher levels of lead in the livers and kidneys. The results revealed that the concentrations of lead in the liver, kidney and meat of beef, mutton and chicken were lower than the permissible limit, while the liver and kidney of caprine were higher than the permissible limit of 1 ppm (ANZFA, 2001) thus indicating contamination of the liver and kidney.

The highest copper concentration was found in the liver of chicken (1.44±0.06 μg/g) and the least value was observed in the meat of chicken (0.1 μg/g). The copper concentration in the liver, kidney and meat of beef, caprine chicken and mutton was below the permissible limit of 200 ppm (ANZFA, 2001). Mukhacheva and Bezel (1995) found higher levels of copper and zinc in the livers and kidneys of mutton and beef. Copper is an essential component of various enzymes and it plays a key role in bone formation, skeletal mineralization and in maintaining the integrity of the connective tissues. Copper is essential for good health, but very high intake can cause health problems such as liver and kidney damage (ATSDR, 2004). Copper can also cause public health hazards in high concentrations (Brito *et al.*, 2005). In humans, 10-30 mg of orally ingested copper from foods stored in copper vessels might cause intestinal discomfort, dizziness and headaches, while excess accumulation of copper in liver may result in hepatitis or cirrhosis and in a hemolytic crisis similar to that seen in acute copper poisoning (Johnson, 1993). However, none of the samples in this study had copper content exceeding the MPL (20 ppm) prescribed by MFPO (1973) in meat products.

The concentrations of iron (Fe) in the liver, kidney and meat organs showed significant variations ($p<0.05$) among beef, mutton, caprine and chicken. The results indicate that the liver of chicken (4.65 ± 0.30 μg/g) contained the highest concentration of Fe, followed by caprine's liver (3.98 ± 0.3 μg/g), while chicken's kidney showed the third highest. The beef meat showed the least concentration (0.98 μg/g).

The concentrations of nickel (Ni) in the liver of beef, mutton, caprine and chicken ranged between 0.19 ± 0.02 and 1.09 ± 0.26 μg/g Table 1, while kidney concentrations ranged from 0.04 ± 0.01 to 0.24 ± 0.01 μg/g Table 2. The levels of Ni ranged between 0.01 and 0.22 μg/g for beef meat, mutton meat, caprine meat and chicken meat respectively as shown in Fig. 1. The highest Ni concentration was observed in the liver of chicken, while lowest value (0.1 μg/g) was found in the caprine meat. Daily intake of small amounts of Mn is needed for growth and good health in humans, otherwise deficiency of Mn can cause nervous system problems (Demirezen and Uruç, 2006). It was observed that the liver of chicken showed the highest Mn concentration of 4.11 ± 0.44 μg/g and the lowest concentration of 0.45 μg/g was observed for beef meat.

Highest cadmium concentration was observed in the kidney of mutton (0.76 ± 0.15 μg/g) Table 1, while the lowest (0.07 μg/g) was in the meat of beef Fig. 1. Cadmium is toxic to virtually every system in the animal body. It is almost absent in the human body at birth, however accumulates with age. Cadmium accumulated in the kidney and liver over long time have been reported by McLaughlin *et al.* (1999) that cadmium interacts with a number of minerals mainly Zn, Fe, Cu and Se due to chemical similarities and competition for binding stage. It is also reported that Cd can affect Ca, P and bone metabolism in both industrial and people exposed to Cd in general environment (Jarup *et al.*, 1998). Aranha *et al.* (1994) and Roga-Franc *et al.* (1996) detected cadmium levels in the livers and kidneys of cattle in Poland and found the cadmium concentration to be above the permissible limit set by (FAO/WHO, 2000). Similarly, Doganoc (1996) found higher levels of cadmium and zinc in the livers and kidneys of the hens and chickens, which exceeded the official tolerance levels. From the results of this study, the concentration of cadmium in all the samples studied were found to be lower than the 0.5 ppm permissible limit set by (FAO/WHO, 2000) with the exception of mutton liver

The highest arsenic concentration (0.34 ± 0.23 μg/g) was observed in the liver of mutton and the lowest value (0.01 μg/g) was found in chicken meat. Higher concentration of arsenic in the livers and kidneys of cattle and goats has also been reported by Krupa and Swida (1997). The permissible limit of arsenic in the livers of chickens has been reported as 2.0 ppm (ANZFA, 2001) and it was found that the highest concentration of arsenic (0.34 ± 0.23 μg/g) was lower than the permissible limit.

Zinc concentration was found to be highest in the liver of caprine (6.23 ± 0.16 μg/g), while the least value was in the meat of chicken (1.1 μg/g). Zinc is an essential element in human diet. Too little Zn can cause problems; however, too much Zn is harmful to human health (ATSDR, 2004). The concentrations of zinc in all the samples studied were below the permissible limit 150 ppm set by (ANZFA, 2001).

CONCLUSION

From the results of this study, the concentrations of all the metals in the liver, kidney and meat of beef, mutton, caprine and chicken were found to be statistically significant ($p<0.05$). Generally, livers and kidneys were found to have the highest significant levels of metals and meat the lowest levels. When compared to one another (beef, mutton, caprine and chicken), there did show significant differences in the levels of heavy metals. Hence, the concentrations of all the metals were within the tolerance limits with the exception of Cr and Pb, which were higher than the ANZFA (2001) tolerance limits.

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REFERENCES

Allan, G., A.C. Robert, D.S.J. O'Reilly, M.J. Stewart and S. James, 1995. Clinical Biochemistry. 2nd Edn., Harcourt Brace and Company Ltd., pp: 114-115.

ANZFA (Australia New Zealand Food Authority), 2001. Wellington NZ 6036 May, 2001. Retrieved from: URL:http://www.anzfa.gov.au.

Aranha, K., 1994. Environmental Chemistry. 3rd Edn., New Age International Ltd. Publisher, New Delhi, pp: 213-219.

ATSDR, 2004. Agency for Toxic Substances and Disease Registry, Division of Toxicology, Clifton Road, NE, Atlanta, GA. Retrieved from: http://www.atsdr.cdc.gov/toxprofiles/.

Baykov, B.D., M.P. Stoyanov and M.L. Gugova, 1996. Cadmium and lead bioaccumulation in male chickens for high food concentrations. Toxicol. Environ. Chem., 54: 155-159.

Brito, G., C. Díaz, L. Galindo, A. Hardisson, D. Santiago and M.F. García, 2005. Levels of metals in canned meat products: Intermetallic correlations. Bull. Environ. Contam. Toxicol., 44(2): 309- 316.

Danev, M., V. Serafimovska, P. Sekulovski, E. Stojkovic, B. Krstic and M. Zoric, 1996. Cadmium contamination of beef. Tehnol. Mesa., 37: 19-21.

Demirezen, D. and K. Uruç, 2006. Comparative study of trace elements in certain fish, meat and meat products. Meat. Sci., 74: 255-260.

FAO/WHO, 2000. Report of the 32nd Session of the codex committee of the food additives Contaminants. Beijing People's Republic of China, 20-24 March.

Cunningham, W.P. and B.W. Saigo, 1997. Environmental Science a Global Concern. 4th Edn., WMC Brown Publisher, New York, pp: 389.

Daniel, B. and A.K. Edward, 1995. Environmental Science, Earth as a Living Planet. John Wiley and Sons, Inc. New York, pp: 278-279.

Doganoc, D.Z., 1996. Distribution of lead, cadmium, and zinc in tissues of hens and chickens from Slovenia. Bull. Environ. Contam. Toxicol., 57: 932-937.

Gonzalez-Waller, D., L. Karlsson, A. Caballero, F. Hernandez, A. Gutierrez, T. Gonzalez-Igalesias., M. Marino and A. Hardission, 2006. Lead and cadmium in meat and meat products consumed by the population in Tenerife Islans, Spain. Food Addit. Contamin., 23: 757-763.

Goyer, R.A., 1997. Toxic and essential metal interactions. Annu. Rev. Nutr., 17: 37- 50.

Horky, D., J. Illek and A. Pechova, 1998. Distribution of heavy metals in calf organs. Vet. Med., 43: 331-342.

Janet, C.K. and L.K. Carl, 1994. Zinc. In: Maurice, E.S., A.O. James, S.L. Moshes and Febiger, (Eds.), Modern nutrition in Health and Disease. 8th Edn., Part I, pp: 227-228.

Institute of Medicine, 2002. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Institute of Medicine of the National Academies. The National Academy Press. Washington D.C. USA.

Jarup, L., M. Berglund, C.G. Elinder and G. Nordberg, 1998. Health effects of cadmium exposure-a review of the literature and a risk estimate. Scand J. Work Environ. Health., 24(1): 1-51.

John, H.H. and I.R. Jeanne, 1994. Food Additives, Contaminants and Natural Toxins. In: Maurice E.S., A.O. James, S.L. Moshe and Febiger, (Eds.), Modern Nutrition in Health and Disease. 8th Edn., Part II, pp: 1597-1598.

Johnson, M.A., 1993. Copper. In: Macrae, R., R.K. Robinson and M.J. Sadler (Eds.), Encyclopaedia of Food Science, Food Technology and Nutrition. Academic Press, London.

Judith, R.T., 1994. Copper. In: Maurice, E.S., A.O. James, S.L. Moshe and Febiger, (Eds.), Modern Nutrition in Health and Disease. 8th Edn., Part I. pp: 237-240.

Koréneková, B., M. Skalická and P. Nad, 2002. Concentration of some heavy metals in cattle reared in the vicinity of metallurgic industry. Veterinarski Arhiv., 72(5): 259-267.

Kostial, K., 1986. Trace Elements in Human and Animal Nutrition. 5th Edn., Hertz, W. (Ed.), Academic Press, Orlando, 2: 319-345.

Krupa, J. and J. Swida, 1997. Concentration of certain heavy metals in the muscles, liver and kidney of goats fattened in the Beiszczady mountains. Anim. Sci., 15: 55-59.

Lo´pez-Alonso, M., J.L. Benedito, M. Miranda, C. Castillo, J. Herna´ndez and R.F. Shore, 2002. Cattle as biomonitors of soil arsenic, copper and zinc concentrations in Galicia (NW Spain). Arch. Environ. Contam. Toxicol., 43: 103-108.

Maldonado, V.M., S.J. Cerbon, A.M. Albores, L.C. Hernandez and J.V. Calderonsalinas, 1996. Lead intestinal absorption and bone mobilization during lactation. Hum. Exp. Toxicol., 15: 872-877.

Mahaffey, K.R., 1977. Mineral concentrations in animal tissues: Certain aspects of FDA regulatory role. J. Anim. Sci., 44: 509-515.

McLaughlin, M.J., D.R. Parker and J.M. Clarke, 1999. Metals and micronutrients- food safety issues. Field Crops Res., 60: 143-163.

MFPO, 1973. The Gazette of India, No. 112. March, 28.

Miranda, M., M. López-Alonso, C. Castillo, J. Hernández and J.L. Benedito, 2005. Effects of moderate pollution on toxic and trace metal levels in calves from a polluted area of northern Spain. Environ. Int., 31: 543-548.

Mukhacheva, S.V. and V.S. Bezel, 1995. Levels of toxic elements and functional structure in populations of small mammals under conditions of technogenic pollution (with reference to the bank vole). Ekologiya, 3: 237-240.

Ozdamar, K., 1991. Biostatistics with SPSS. Kann Press Eskisehir, pp: 2-23.

Reddy, A.T.V. and K. Yellamma, 1996. Cadmium chloride induced alteration in the detoxification enzymes of rat liver and kidney. Pollut. Res., 15: 371-373.

Roga-Franc, M., T. Kosla and E. Rokicki, 1996. Cadmium concentration in organs of dairy cows depending on that element contents in meadow cover. Mengen-Spurenelem., Arbeistag., pp: 393-397

Sabir, S.M., S.W. Khan and I. Hayat, 2003. Effect of environmental pollution on quality of meat in district Bagh, Azad Kashmir. Pak. J. Nutr., 2(2): 98-101.

Santhi, D., V. Balakrishnan, A. Kalaikannan and K.T. Radhakrishnan, 2008. Presence of heavy metals in pork products in Chennai (India). Am. J. Food Technol., 3(3): 192-199.

SCAN, 2003. Scientific Committee on Animal Nutrition: Opinion of the Undesirable Substances in Feed. Retrieved from: http://europa.eu.int/comm/food/fs/sc/scan/out126_bis_en.pdf, (Accessed on: 25 April, 2003).

Spierenburg, T.J., G.J. De-Graaf and A.J. Braars, 1988. Cadmium, zinc, lead and copper in livers and kidney of cattle in the neighborhood of zinc refineries. Environ. Monit. Assess., 11: 107-114.