DETERMINATION OF SOME HEAVY METAL PROFILES IN MEAT OF DOMESTICATED ANIMALS IN THE VICINITY OF KADUNA SOUTH INDUSTRIAL AREA, NIGERIA

Supported by tetfund TERTIARY EDUCATION TRUST FUND

R. Odoh*, E. Ogah and O.A. Ushie

Department of Chemical Sciences, Federal University Wukari, PMB 1020, Taraba State, Nigeria

*****Corresponding author: odohraf@gmail.com

Received: June 25, 2016 **Accepted:** August 27, 2016

Abstract: The determination of Cd, Cr, Cu, Fe,Mn, Ni, Pb and Zn contents in fresh meats; cow meat (beef), sheep meat (mutton), goat meat (caprine) pig meat (pork) and foul meat (chicken) found in the industrial area of Kaduna south were carried out with Flame Atomic Absorption spectrophotometric technique. Samples were treated in triplicate and analyses were carried out following EPA Method 3050B digestion procedures. The overall results ranged from 0.001-0.076, 0.001-0.092, 0.023-1.955, 0.110-0.999, 0.078-0.922, 0.011-0.095, 0.011-0.065 and 1.011-2.971 μg/g for Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn, respectively. The mean concentrations of heavy metals obtained from the meats of the same species of animals from the remote area (control) were much lower than those obtained from the meat samples of actual samples. This reflects a general contamination of the meats by the heavy metals studied. All parameters examined in the meat samples have values that are below or within the maximum permissible limit of WHO, FAO and EC Standards, hence the present result may not pose any serious health hazard but does call for close monitoring of these heavy metals in meat products meant for human consumption.

Keywords: Heavy metals, meat, contamination, industrial area, bioaccumulation, toxicity

Introduction

Heavy metals are naturally present in the environment, their occurrence, however, has gradually been increasing with the increase in industrialization. Accumulation of toxic metals in the environment as a result of pollution by industrial and urban activities has generated global health concerns due to the risks of such chemical ending up in the food chains (Goyer, 1997). Agricultural lands within industrial areas or close to highways have been observed to be grossly contaminated with heavy metals due to aerial deposition of metal containing particulates from automobile exhausts, and consequently being taken up by crops. Heavy metals present in the environment constitute serious environmental hazards from the point of view of polluting the soils and adjoining streams and rivers. Some agricultural soils are often irrigated with industrial and city effluents leading to the introduction of some toxic elements into the soil. These are taken up by plants and eventually transferred into tissues of grazing animals and man. Animals that graze on such contaminated plants and drink from polluted waters, as well as marine lives that breed in heavy metal polluted waters also accumulate such metals in their tissues, and milk, if lactating. Humans are in turn exposed to heavy metals by consuming contaminated plants and animal products such as meats and milks, and this has been known to result in various biochemical disorders. Ingestion of these contaminants by animals causes deposition of residues in meat. Due to the grazing of animals on contaminated environment, higher levels of metals have been found in beef and mutton (Sabir *et al.*, 2003; Gonzalez-Waller *et al.*, 2006).

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. Contamination of meats with heavy metals is a serious threat because of their toxicity, bioaccumulation and biomagnifications in the food chain (Demirezen & Uruç, 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 (Horky *et al.*, 1998).

Meat is most important source of protein to millions of people worldwide. It is known to be one of the cheapest sources of protein and other essential nutrients required in human diets (Sadiku & Oladimeji, 1991). All over the world, most of the protein intake comes from meats, while in Africa, the proportion is very high (Williams *et al.*, 1988). In Nigeria, meat has an edge over other sources of protein because it is relatively more abundant in all part of Nigeria especially in the Northern part of Nigeria (Eyo, 2006) and constitutes about 70% of the protein intake (Olatunde, 1998). In Africa, especially Nigeria, meat and meat products from domestic animals (chicken meat, the liver, kidney and meat of goat, pig, sheep and cow) are major sources of protein to the population and are widely consumed. The main source of metals in meats especially 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 vehicular emission and from dirty abattoirs.

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; 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 (Daniel & Edward 1995; Sabir *et al.*, 2003): Koréneková *et al.*, 2002).

Although there have been considerable number of studies on the concentration of heavy metals in Kaduna south metropolis, the vast majority have been carried out on soil, water and fishes, and none has been carried out on meat from domestic animals around that area and data on heavy metal concentrations and distributions in such important products are extremely scarce. This study was designed to compare the levels of heavy metals (lead, cadmium, chromium, cobalt, copper, iron, manganese, nickel and zinc) in meat from these domestic animals the industrial areas of Kaduna south in Kaduna metropolis and similar domestic animals from remote village were industrial and other commercial activities were absent.

Material and Methods

Materials

Sample collection

All reagents used in this research were purchased from Sigma Aldrich, and were of analytical grade and needed no further purification. Fresh meats of cow meat (beef), sheep meat (mutton), goat meat (caprine), pig meat(pork) and fowl meat (chicken) were bought from the study area (Ungwan Kakuri, Ungwan Television, nassarawa and Barnawa) Kaduna south of Kaduna state, while meat from same animals at (Sabon Gaya) far from the study area were also bought and used as a control. The samples and control were collected in plastic containers and transported to the laboratory for analysis. The predominant activities at the study areas were tanning and various agricultural practices.

Sample preparation

The collected samples were decomposed by wet digestion method for the determination of various metals. Samples were treated in triplicate and analysis was carried out following EPA Method 3050B acid digestion Procedures (USEPA, 1986). A procedure recommended by Environmental Protection Agency (EPA, Method 3050B) was used as the conventional acid extraction method. Briefly, 1.00 g of meat sample was placed in 250 mL flask for digestion. The first step was to heat the sample to 95^{o}C with 10 mL of 50% HNO_3 without boiling. After cooling the sample, it was refluxed with repeated additions of 65% HNO_3 until no brown fumes were given off by the sample. Then the solution was allowed to evaporate until the volume was reduced to 5 mL. After cooling, 10 mL of 30% H_2O_2 was added slowly without allowing any losses. The mixture was refluxed with 10 mL of 37% HCl at 95^{o}C for 15 min. The digestate obtained was filtered through a 0.45 µm membrane paper, diluted to 100 mL with deionized water and stored at 4^{o}C for analysis. The total extraction procedure lasted for 3–4 h.

Elemental analysis of samples

The instrument used was first calibrated with stock solutions of the prepared standards before analysis. The final processed samples were quantitative analyzed using buck scientific VGP 210 Flame Atomic Absorption Spectrophotometer. After every five sample analyzed using AAS, the first sample was repeated for quality check. Only when the results were within 10% earlier readings did the analyses proceed further.

Results and Discussion

The concentrations of the heavy metals found in pork, mutton, caprine and chicken are presented in tables 1, 2, 3, and 4, respectively while figures 1-4 makes the corresponding presentation of the concentrations of elements in pork, mutton, caprine and chicken. Control samples of the same meat of animals were taken from the remote part of the study where there were no industrial activities.

Table 1: Heavy metal content of pork from the study areas (µg/g)

Locations	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
UKK 1	0.076	0.057	1.112	0.511	0.922	0.095	0.054	2.123
UKK 2	0.063	0.059	1.955	0.521	0.831	0.065	0.053	2.971
UKK 3	0.042	0.049	1.856	0.975	0.701	0.075	0.053	2.554
UTV 4	0.035	0.035	1.788	0.545	0.744	0.067	0.054	2.065
UTV 5	0.045	0.056	1.678	0.533	0.875	0.061	0.054	2.876
UTV 6	0.065	0.088	1.835	0.859	0.666	0.087	0.065	1.997
NSW 7	0.075	0.045	1.699	0.522	0.698	0.092	0.055	2.543
NSW 8	0.054	0.075	1.589	0.789	0.844	0.077	0.052	2.234
NSW 9	0.048	0.067	1.023	0.521	0.689	0.054	0.053	2.543
BNW10	0.053	0.073	1.011	0.516	0.801	0.071	0.054	2.675
BNW11	0.063	0.092	1.955	0.999	0.788	0.055	0.053	2.654
BNW12	0.028	0.088	1.654	0.512	0.732	0.085	0.055	2.098
SBG 13	0.067	0.075	1.896	0.510	0.841	0.065	0.061	2.012
SBG 14	0.057	0.077	1.105	0.892	0.887	0.081	0.054	2.122
SBG 15	0.033	0.054	1.786	0.540	0.771	0.075	0.057	1.987
Mean	0.054	0.066	1.596	0.650	0.786	0.074	0.055	2.364
STD	0.015	0.017	0.350	0.191	0.080	0.013	0.003	0.339
MIN	0.028	0.035	1.011	0.510	0.666	0.054	0.052	1.987
MAX	0.076	0.092	1.955	0.999	0.922	0.095	0.065	2.971

Ungwa Kakuri (UKK), Ungwa Television (UTV), Nassarawa (NSW) and Barnawa (BNW), Sabon Gaya (SBG).

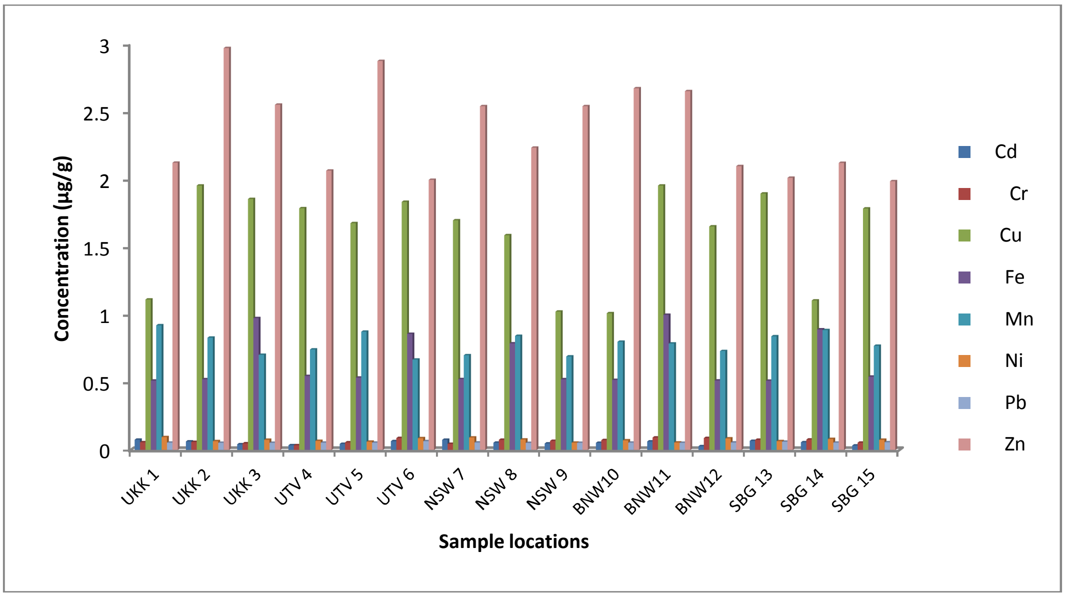

Fig. 1: Heavy metal concentrations of pork

Table 2: Heavy metal content of mutton from the study areas (μg/g)

Locations	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
UKK 1	0.001	0.001	0.039	0.181	0.122	0.001	0.021	1.123
UKK 2	0.001	0.001	0.030	0.152	0.131	0.001	0.031	1.971
UKK 3	0.002	0.001	0.036	0.198	0.201	0.002	0.012	1.554
UTV 4	0.001	0.001	0.029	0.125	0.144	0.001	0.024	1.011
UTV 5	0.002	0.002	0.028	0.133	0.175	0.002	0.023	1.876
UTV 6	0.001	0.002	0.024	0.186	0.166	0.001	0.025	1.997
NSW 7	0.002	0.003	0.030	0.122	0.098	0.001	0.025	1.543
NSW 8	0.001	0.001	0.029	0.179	0.144	0.001	0.022	1.234
NSW 9	0.001	0.003	0.034	0.121	0.089	0.002	0.032	1.543
BNW10	0.001	0.001	0.025	0.116	0.201	0.001	0.031	1.675
BNW11	0.002	0.002	0.026	0.200	0.321	0.001	0.033	1.654
BNW12	0.002	0.003	0.037	0.112	0.132	0.001	0.025	1.098
SBG 13	0.001	0.002	0.030	0.110	0.141	0.001	0.031	1.133
SBG 14	0.001	0.001	0.026	0.189	0.122	0.002	0.031	1.098
SBG 15	0.001	0.003	0.029	0.140	0.171	0.001	0.028	1.987
Mean	0.001	0.002	0.030	0.151	0.157	0.001	0.026	1.500
STD	0.001	0.001	0.005	0.034	0.060	0.001	0.006	0.360
MIN	0.001	0.001	0.024	0.110	0.089	0.001	0.012	1.011
MAX	0.002	0.003	0.039	0.200	0.321	0.002	0.033	1.997

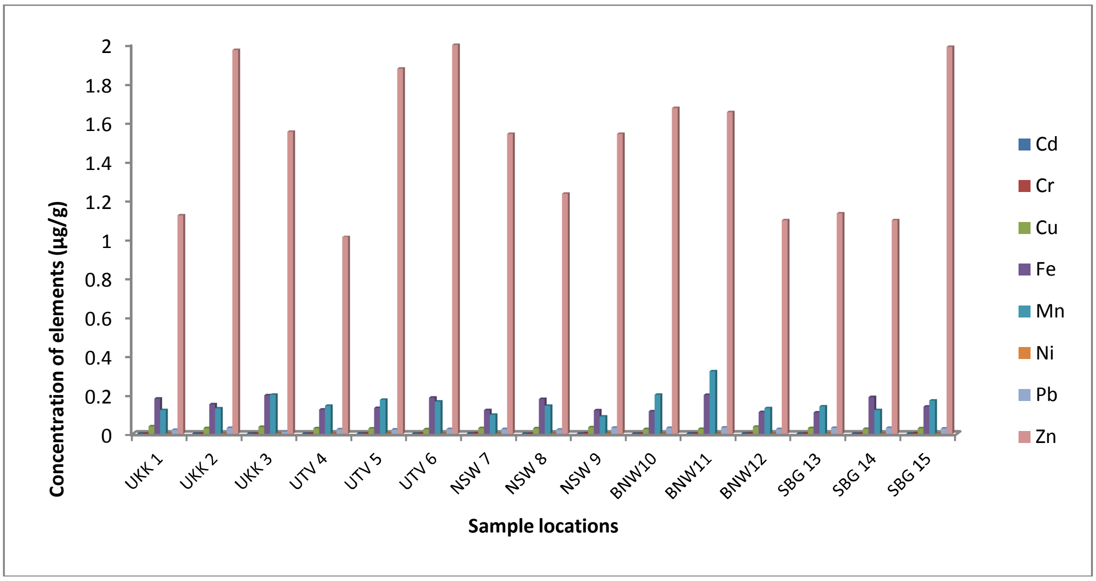

Fig. 2: Heavy metal concentrations of mutton

The result of the analysis revealed elevated levels of Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn determined in the meat samples from the study areas. The mean concentrations of heavy metals obtained from the meats of the same animals from the remote area (control) were consistently much lower than those obtained from the meat sample under consideration. This reflects a general contamination of the meats by the heavy metals due to the mode of feeding of animals and the anthropogenic activities at the studied. The overall results ranged from 0.001–0.076, 0.001–0.092, 0.023–1.955, 0.110–0.999, 0.078–0.922, 0.011–0.095, 0.011–0.065 and 1.011–2.971 µg/g for Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn, respectively. The concentration of all the trace heavy metals determined in the meat (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) were higher in all the meat samples of the animals studied when compared with the corresponding values in the same meat from remote area i.e. control (SBG 13-15). Cd, Cr, Ni and Pb were detected in all the meat samples analyzed. However, Cd, Cr, Ni and Pb were not detected in meats from control area.

The closeness of the concentrations of the qualitative similarity of the h heavy metals in the meat samples is an indication that all the meat samples are from the same geographical area and animals feed on similar food materials. Because of the complicated pattern in the concentration relationship of the samples, focusing on the comparison between the meat samples will be futile; instead, the general profile of each heavy metal will be discussed focusing attention to any anomaly. The little discrepancies in the differing quantitative pattern among the samples were expected. The reason may hinge on several factors. For instance, heavy metal levels of meat may depend on the age, mode, and type of feeding, meat processing and packaging (Jarup *et al.,* 1998; Baykov *et al.,* 1996).

Therefore, from the results (Table 1, 2, 3 and 4), Cd, Cr, Ni, and Pb indicates levels of concentrations which could be carcinogenic (Baykov *et al.,* 1996). Even though heavy metals present in meat do not entirely determine the risk likely to be caused by meat consumptions, they can become more hazardous where they are present in higher concentrations, and could lead to higher health risk. Special attention has been given to the elements that play a significant toxicological role after entering the human body through meat consumption or uses of other meat products. Contamination of the meat with heavy metals could pose potential health risk to humans and other animals because these heavy metals have the ability to "bioaccumulate". Reports from previous research have shown that compounds accumulate in living things any time they are taken up and stored faster than they are metabolized or excreted (Danev *et al.,* 1996; Doganoc, 1996).

All the meat of the domestic animals at the study areas (Kaduna south industrial area) analyzed contained detectable amounts of these heavy metals of interest. Pb, a ubiquitous and versatile metal was also detected in all the samples. Pb has become widely distributed and mobilized in the environment and human exposure to and uptake of this non-essential element has consequently increased (Doganoc 1996). At high levels of human exposure, there is damage to almost all organs and systems, most importantly the central nervous system, kidneys and blood, culminating in death at excessive levels. At low levels, haem synthesis and other biochemical processes have been reported to be affected by lead contamination (Marino & Hardission, 2006).

Lead continues to be a significant public health problem in developing countries where there are considerable variations in the sources and pathways of exposure, therefore care need to be taking in the consumption of Pb contaminated meat and meat products since Pb exposure is through direct contact. The maximum limit of 0.02 µg/g Cd in plant and 5.0 µg/g Pb in plant was prescribed by WHO/FAO (FAO/WHO, 2000). The values for the standard compared to our work indicate Cd contamination of some the meat samples analyzed in the study areas, especially in the pork (pig meat) where concentration range of 0.0280–0.0760 µg/g was recorded (Table 1). Chromium is considered non-essential for plants, but an essential element for animals. Cr toxicity in man has been limited to haemorrhage, respiratory impairment and liver lesions. Low exposure to chromium can irritate the skin and cause ulceration. Long term exposure can cause kidney and liver damage. It can also cause damage to circulatory and nerve tissues. In this work, Cr was found to range between 0.0010–0.0920 µg/g with an average of 0.0660±0.0170 µg/g. This value is less than 150 µg/g safe limits, giving by EU commission regulation (Baykov *et al.,* 1996). Cr concentration in this study is lower than 0.1000 µg/g maximum limit set by WHO/FAO (FAO/WHO, 2000). Levels of Ni in all the meat sample products analyzed from each the study areas were almost similar, the slight differences in their concentration were not statistically significant at $p<0.5$. The mean Ni concentration in the sample products (0.0263±0.0273 µg/g), it is important to note that Ni concentrations in all the meat samples investigated were lower than what was obtained by other researchers in the similar studies (Lo'pez-Alonso *et al.,* 2002). Nickel apparently has a limited acute toxicity in humans, including airway irritation, but the important adverse effects relate to allergic eczema and respiratory cancers (Baykov *et al.,* 1996; Aranha, 1994). Excessive amounts of nickel can be mildly toxic. Long term exposure can cause decreased body weight, heart and liver damage and skin irritation; the symptoms of exposure to some poisonous nickel compounds include nausea, vomiting, headaches and sleeplessness. The symptoms get worse later on from 12 to 24 h after exposure and include a speeding heart, difficult breathing, chest pains and extreme fatigue.

The mean level of Cu in the meat samples studied was 0.3508±0.6452 µg/g while that of Fe was (0.2759±0.2091 µg/g). Copper and iron are classified as essential to life due to their involvement in certain physiological processes, but elevated levels of these elements, however, have been found to be toxic. Copper and Fe form the essential group of metals required for some metabolic activities in organisms. Toxicological effects of large amounts of copper can cause anaemia, liver and kidney damage, and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from over exposure to copper. Mn concentration in all the samples studied ranged from 0.0780 – 0.9220 µg/g and higher concentration of Mn was detected in the pork (pig meat). Manganese is known to block calcium channels and with chronic exposure results in CNS dopamine depletion. This duplicates almost all of the symptomology of Parkinson's disease.

The mean and range values (Table 1-4) of Cu, Fe and Mn in all the meat samples studied revealed that the levels of these metals were lower than the regulatory limit for World Health Organization (FAO/WHO, 2000) i.e (0.1

mg/kg, 0.3 mg/kg, 0.3 mg/kg) but higher than the value in the meats from control area.

The mean concentration of Zn in the meat samples analyzed ranges from 1.0110–2.9710 µg/g. Thus in the present study, the highest amount of Zn found in the samples is much lower than the permissible level of 250 µg/g (Marino and Hardission, 2006; FAO/WHO, 2000). However, these values are similarly related to those reported in several studies (Lo'pez-Alonso *et al.;* Aranha, 1994) and although humans can handle proportionally large concentrations of zinc, too much zinc can still cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis (Cunningham & Saigo, 1997).

Table 3: Heavy metal content of caprine from the study areas (µg/g)

Locations	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
UKK 1	0.001	0.001	0.030	0.181	0.122	0.001	0.021	1.123
UKK 2	0.001	0.002	0.030	0.152	0.131	0.001	0.031	1.971
UKK 3	0.002	0.001	0.036	0.198	0.201	0.002	0.012	1.554
UTV 4	0.001	0.001	0.029	0.125	0.144	0.001	0.024	1.011
UTV 5	0.002	0.002	0.028	0.133	0.175	0.002	0.023	1.876
UTV 6	0.001	0.002	0.024	0.186	0.166	0.001	0.025	1.997
NSW 7	0.002	0.003	0.030	0.122	0.098	0.001	0.025	1.543
NSW 8	0.001	0.001	0.029	0.179	0.144	0.001	0.022	1.234
NSW 9	0.001	0.003	0.034	0.121	0.089	0.002	0.032	1.543
BNW10	0.001	0.001	0.025	0.116	0.201	0.001	0.031	1.675
BNW11	0.002	0.002	0.026	0.200	0.321	0.001	0.033	1.654
BNW12	0.002	0.003	0.037	0.112	0.132	0.001	0.025	1.098
SBG 13	0.001	0.002	0.030	0.110	0.141	0.001	0.031	1.133
SBG 14	0.001	0.001	0.026	0.189	0.122	0.002	0.031	1.098
SBG 15	0.001	0.003	0.029	0.140	0.171	0.001	0.028	1.987
Mean	0.001	0.001	0.030	0.151	0.157	0.001	0.026	1.500
STD	0.001	0.001	0.005	0.034	0.056	0.001	0.006	0.360
MIN	0.001	0.001	0.024	0.110	0.089	0.001	0.012	1.011
MAX	0.002	0.003	0.039	0.200	0.321	0.002	0.033	1.997

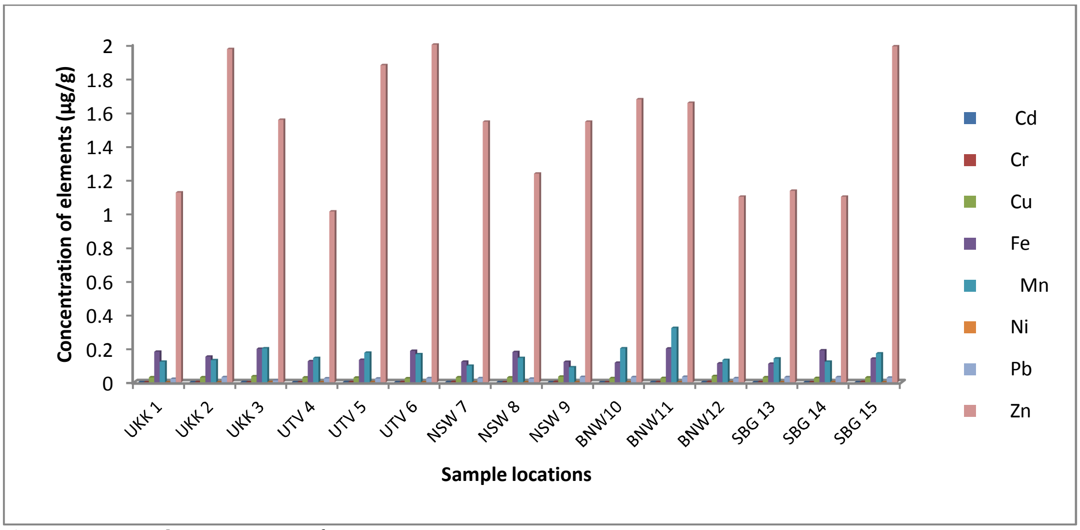

Fig. 3: Heavy metal concentrations of caprine

Table 4: Heavy metal content of chicken from the study areas (µg/g)

Locations	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
UKK 1	0.002	0.023	0.043	0.251	0.122	0.025	0.012	1.231
UKK 2	0.001	0.012	0.023	0.232	0.131	0.025	0.017	1.971
UKK 3	0.004	0.022	0.06	0.198	0.765	0.035	0.012	1.554
UTV 4	0.004	0.011	0.079	0.225	0.144	0.027	0.011	1.767
UTV 5	0.003	0.012	0.068	0.233	0.175	0.031	0.013	1.876
UTV 6	0.001	0.028	0.053	0.186	0.166	0.027	0.018	1.997
NSW 7	0.001	0.017	0.070	0.222	0.098	0.032	0.021	1.543
NSW 8	0.002	0.021	0.059	0.179	0.144	0.027	0.016	1.234
NSW 9	0.002	0.025	0.032	0.221	0.089	0.024	0.011	1.543
BNW10	0.002	0.029	0.043	0.216	0.201	0.031	0.019	1.675
BNW11	0.002	0.026	0.044	0.200	0.078	0.025	0.014	1.654
BNW12	0.003	0.019	0.033	0.212	0.132	0.025	0.012	1.098
SBG 13	0.001	0.018	0.044	0.210	0.141	0.035	0.013	1.123
SBG 14	0.002	0.029	0.039	0.189	0.211	0.021	0.011	1.543
SBG 15	0.002	0.023	0.040	0.240	0.171	0.025	0.028	1.987
Mean	0.002	0.021	0.049	0.214	0.185	0.028	0.015	1.586
STD	0.001	0.006	0.016	0.021	0.165	0.004	0.005	0.307
MIN	0.001	0.011	0.023	0.179	0.078	0.021	0.011	1.098
MAX	0.0042	0.029	0.079	0.251	0.765	0.035	0.028	1.997

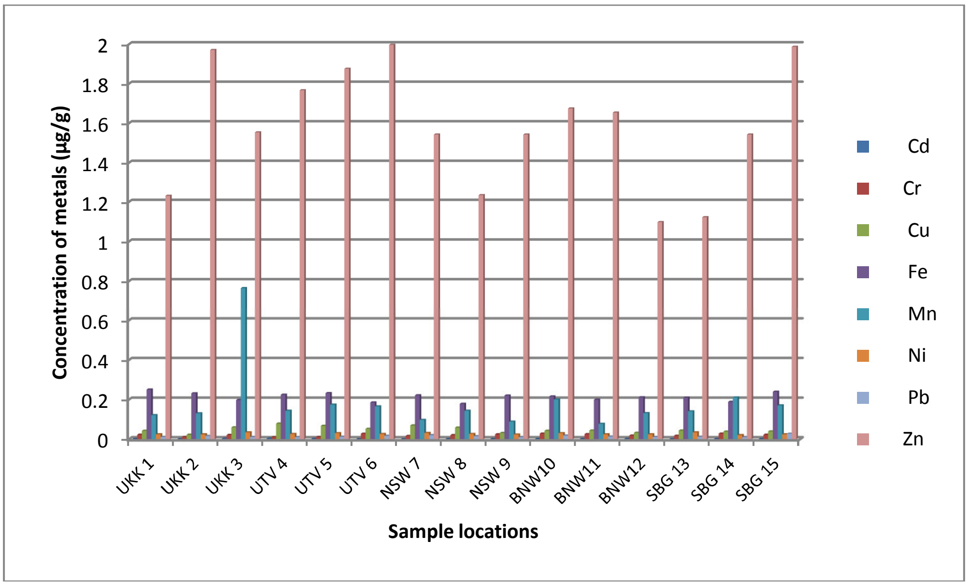

Fig. 4: Heavy metal concentrations of chicken

From the range and mean values, there is a clear indication that the level of heavy metals in meat of a domestic animals reared in Kaduna south industrial areas is higher than the level of heavy metals found in the meat of domestic animals from the remote area of Kaduna State and the levels found in these domestic animals from industrial area may be attributed to discharge, and other industrial activities in the areas that can releases metals to the environment. Although all the heavy metal determined were present in all the meat samples analyzed but the present concentrations may not pose any serious health hazard since the concentration are below or within WHO limit but attention should be given Cd, Ni and Pb that were presented in meat of domestic animals from study areas but not in the meat from control areas.

Conclusion

A comprehensive study of some heavy metal concentration in the meat of domestic animals from industrial area of Kaduna south of Kaduna state has been carried out in this study. Regular and popular domestic animals studied in the Kaduna south industrial areas contained all the heavy metals determined at various concentrations. The presence of some of these heavy metals (Cd, Cr, Ni, and Pb) in the meat of domestic animals in Kaduna south industrial area as opposed to the meat of domestic animals from remote areas (control) is probably as a result of industrial activities in the area which resulted in the release of these metals into the environment i.e. air, water, soil and vegetation. The mean concentrations of heavy metals obtained from the meats of the same animals from the remote area (control) were consistently much lower than those obtained from the meat sample under consideration. This reflects a general contamination of the meats by the heavy metals studied. However the study is of the view that the consumption of some of the meat of domestic animals in Kaduna south industrial areas could result in an increase in heavy and trace metals in the human body beyond acceptable limits through bioaccumulation.

References

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

Baykov BD, Stoyanov MP & Gugova ML 1996. Cadmium and lead bioaccumulation in male chickens for high food concentrations. *Toxicol. Environ. Chem.*, 54: 155-159.

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

Cunningham WP & Saigo BW 1997. *Environmental Science a Global Concern*. 4th Edn., WMC Brown Publisher, New York, p. 389.

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

Daniel B & Edward AK 1995. Environmental Science, Earth as a Living Planet. JohnWiley and Sons, Inc. New York: Pp 278-279.

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

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

Eyo AA 2006. *Fish Processing Technology in the Tropics*. University of Ilorin Press, pp. 104 – 189.

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.

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

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

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

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

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

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

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

Marino M & Hardission A 2006. Lead and cadmium in meat and meat products consumed by the population in Tenerife Islans, Spain. *Food, Addit. Contamin.*, 23: 757-763.

Olatunde AA 1998. Approach to the study of fisheries biology in Nigerian inland water. Proceedings of International Conference of two Decades of Research in Lake Kainji, 338–541.

Sabir SM, Khan SW & Hayat I 2003. Effect of environmental pollution on quality of meat in district Bagh, Azad Kashmir. *Pak. J. Nutr.*, 2(2): 98-101.

Sadiku SOE & Oladimeji AA 1991. Relationship of proximate composition of *Latesniloticus* and *Synodontisschall* and *Sarotherodongalilaeus* (Trewavas) from Zaria Dam, Nigeria. *Biosci. Res. Comm.*, 3(1): 29-40.

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

US Environmental Protection Agency 1986. Test Methods of Evaluation for Solid Waste (USEPA S/W 846 UEPA, Washinton DC .

Williams R, Halwart M & Barg U 1988. Integrated fisheries and agriculture to enhance fish production and food security. *FAO Aquaculture Newsletter*, 20, 3-8.