

Accumulation of Metals in the Liver and Kidneys of Cattle from Agricultural Areas in Lusaka, Zambia

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ABSTRACT. Intensive agricultural practices are recognized as significant sources of metal pollution in soils and pasture. This study investigated metal contamination in cattle offal from an agricultural area in Zambia, where inorganic fertilizers, agricultural lime, and pesticides are routinely applied. The highest median values (mg/kg, wet weight) of Cu (40.9), Zn (35.2), Cr (1.35) and Ni (0.594) were recorded in the liver, whereas the highest median values of Pb (0.061) and Cd (0.049) were found in kidneys. Maximum levels of Hg, As and Co were under 0.2 mg/kg in both organs. Pb and Cd did not exceed the benchmark values in cattle offal for human consumption and did not pose immediate health risks. Concentrations of Ni and Cr could present a public health concern. Monitoring of metal accumulations in offal of cattle, not only from well-known polluted environments but also agricultural areas, should be done regularly for the health of human consumers.

KEY WORDS: cattle, kidney, liver, metal accumulation, Zambia.

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The accumulation of toxic metals in food animals is recognized as a public health hazard worldwide. Toxic metals can be lethal and tend to accumulate in the liver, kidneys, bones, and other tissues [8]. Metals including Pb, Cd, Hg, and As are readily transferred through food chains and pose potential health risks to human consumers. Sources of metal contamination in livestock production systems can be natural and anthropogenic. In agricultural systems that integrate livestock and crop production, intensive agricultural practices are recognized as significant sources of metal accumulation [9]. Fertilizers and agricultural lime contain metal impurities, and it is widely reported that application of these agrochemicals, especially phosphate fertilizers, results in accumulation of metals in agricultural soils [9, 12]. Metallo-pesticides, including insecticides, fungicides, and herbicides, are also known to contain various metals that can increase metal accumulation [12]. Thus, the present study determined Pb, Cd, Hg, As, Ni, Cr, Cu, Zn, and Co concentrations in the liver and kidneys of cattle from an agricultural area in Zambia to provide a preliminary assessment of metal accumulation in cattle offal, and the potential risks to human consumers as cattle liver and kidneys are widely consumed in Zambia.

Paired liver and kidney samples were collected in October, 2009 from 112 mixed breed male and female adult cattle slaughtered at abattoirs in Lusaka (latitude 15° 25' S, longitude 28° 16' E), the capital city of Zambia. Cattle slaughtered at these abattoirs came from commercial farms in the Chisamba agricultural block, located approximately 50 km north of Lusaka City. Samples were transported to the Graduate School of Veterinary Medicine, Hokkaido University, Japan for metal concentration analysis.

Metals (except for Hg) were extracted from the liver and kidney samples by acid digestion using the method of Nakayama [7] with minor modifications. The concentrations of metals in the digested samples were determined using a flame/flame-less atomic absorption spectrophotometer (AAS, Z-2010, Hitachi High-Technologies Corporation, Tokyo, Japan) equipped with a Zeeman graphite furnace. Mercury was measured by thermal decomposition, gold amalgamation, and atomic absorption spectrophotometry (Mercury Analyzer, MA-3000, Nippon Instruments Corporation, Tokyo, Japan). Analytical quality control was performed using the DOLT-4 (Dogfish liver, National Research Council of Canada, Ottawa, Canada) certified reference material. Recovery rates (%) of all elements were acceptable; Pb (89–98), Cd (91–108), Hg (92–103%), Ni (98–111), Cr (91–108), Cu (88–90), Zn (78–83) and Co (96–111) except for As (50–67%). Detection limits ($\mu\text{g/kg}$ dry weight) of Pb, Cd, Ni, Cr, Cu, Zn, Co and As were 1.0, 0.2, 0.5, 0.5, 1.0, 0.1, 0.5 and 2.0, respectively. The detection limit of Hg was 2.0 pg of total Hg. Concentrations of metals were expressed as mg/kg wet weight.

Metal concentrations in the liver and kidneys were log

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Table 1. Median, quartiles (first and third), and minimum to maximum concentrations (mg/kg, wet weight) of metals in the liver and kidneys of cattle from Lusaka, Zambia

	Pb	Cd	Hg	As	Ni	Cr	Cu	Zn	Co
Liver (n=112)									
Minimum	0.012	0.001	ND	ND	0.005	ND	0.571	26.8	ND
1st quartile	0.037	0.005	0.0002	0.001	0.242	0.943	27.6	32.3	0.03
Median	0.047	0.009	0.0003	0.002	0.594	1.35	40.9	35.2	0.039
3rd quartile	0.066	0.013	0.001	0.003	1.07	2.84	61.3	39.6	0.053
Maximum	0.133	0.061	0.027	0.01	23.2	14.9	159.0	63.9	0.195
Kidney (n=112)									
Minimum	0.007	0.001	0.0001	0.0004	0.038	0.349	1.71	16.3	0.013
1st quartile	0.037	0.034	0.002	0.003	0.086	0.738	3.08	19.7	0.025
Median	0.061	0.049	0.004	0.005	0.131	1.07	4.13	21.5	0.029
3rd quartile	0.093	0.076	0.005	0.007	0.224	1.72	4.68	24.3	0.034
Maximum	0.271	1.15	0.015	0.028	6.44	15.2	11.9	41.4	0.049

Note: ND—Not detectable.

transformed to stabilize variances. Statistical analysis was performed using JMP® version 9 (SAS Institute, Cary, NC, U.S.A.). Data were presented as median, quartiles (first and third), and minimum to maximum values (mg/kg wet weight). Spearman correlation was used to analyze the association in the accumulation of toxic metals between the liver and kidneys. A *P* value less than 0.05 was considered to indicate statistical significance.

Table 1 shows the concentrations of Pb, Cd, Hg, As, Ni, Cr, Cu, Zn, and Co in the liver and kidneys of cattle from commercial farms in Lusaka, Zambia. The highest median values (mg/kg, wet weight) of Cu (40.9), Zn (35.2), Cr (1.35) and Ni (0.594) were recorded in the liver, whereas the highest median values of Pb (0.061) and Cd (0.049) were found in kidneys. There were no correlations in the accumulation of toxic metals between the liver and kidneys.

The overall median concentrations of toxic metals including Pb, Cd, Hg, and As were lower than the 0.5–1 mg/kg wet weight upper limit in cattle offal for human consumption [3]. The levels of Pb and Cd in the present study were lower than those previously reported by Yabe *et al.* [15] in cattle offal from Kabwe, a Pb-Zn mining town in the central province of Zambia. Studies in cattle from polluted environments in other countries have reported Pb and Cd accumulations exceeding the benchmark values in offal [10, 11, 13]. Although toxic metal concentrations in the current study were low and did not pose immediate health risks, the levels of Pb and Cd indicate potential for increased accumulation, if exposure is prolonged as these metals bioaccumulate and bioconcentrate in organs and tissues of animals [14]. The low levels of Hg and As in the present study agreed with findings in other studies [5, 15], and they posed no immediate health risk to human consumers.

Ni and Cr are considered as essential trace elements, and there are no benchmark values for cattle offal destined for human consumption. In the current study, median levels of 0.594 mg/kg wet weight Ni and 1.35 mg/kg Cr in the liver were comparable to the concentrations reported previously in cattle from polluted regions in Zambia [15]. Although literature on Ni and Cr contamination in cattle offal is scarce,

lower mean levels of Ni and Cr reaching only 0.23 mg/kg wet weight were recorded in the liver and kidneys of ruminants in the Netherlands [2], Sweden [4], and the Slovak Republic [6]. Based on these comparisons, it is evident that the Ni and Cr contamination of cattle offal in Zambia appears to be relatively higher than previous reports in cattle offal. Given that concentrations of Ni and Cr reached up to 23.2 and 15.2 mg/kg, respectively, the health risk to human consumers should be given consideration as these metals are toxic and carcinogenic [1]. Thus, the contribution of cattle offal to the total intake of Ni and Cr in human consumers should be monitored, as cattle offal are considered as delicacies and frequently consumed in Zambia and other countries. The median concentrations of Cu (40.9 mg/kg) and Zn (35.2 mg/kg) in the liver were similar to concentrations found in cattle from polluted environments [6, 15].

Cattle in the present study were reared on commercial farms away from industrial and mining activities. Therefore, commercial farming involving prolonged application of fertilizers and the natural presence of metals in soils could have contributed to metal accumulation either singly or combined. Given the above, more studies are needed to determine metal concentrations in agrochemicals applied on the farms, metal deposits in soils and accumulation in grazing animals in order to evaluate the impact of agricultural practices on metal accumulation in farm animals and the possible health risks to human consumers.

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