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Descriptive Analysis of Heavy Metals Content of Beef From Eastern Uganda and Their Safety for Public Consumption

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Abstract

In this study, we initiated an effort to generate information about beef safety in Uganda. Our entry point was to assess by atomic absorption spectrophotometry the levels of essential elements copper (Cu), cobalt (Co), iron (Fe) and zinc (Zn), and non-essential elements lead (Pb), chromium (Cr), nickel (Ni), and cadmium (Cd) in 40 beef samples collected from within and around Soroti (Uganda). The information was used to evaluate the safety of consuming such beef against the World Health Organization (WHO) limits. The latter was accomplished by (i) estimating the daily intake (EDI) of each metal in the study area, (ii) modeling the non-cancer health risk using the target hazard quotient (THQ) and (iii) modeling the cancer risk using the incremental lifetime cancer risk (ILCR). The study finds that the mean concentrations (±95% CI) and EDI were in the order of Fe > Zn > Cr > Ni > Pb > Co > Cu > Cd. Cancer risk was found to be due to Ni > Cr > Cd > Pb and significantly higher in children than adults. The latter particularly demonstrates the importance of Ni poisoning in the study area. Overall, while essential elements in our beef samples were below WHO limits (hence no health risks), non-essential elements had high health and cancer risks due to higher levels of Cr and Ni.

Keywords: heavy metals, food hygiene, food safety, Uganda, beef industry

Introduction

Contamination of food by heavy metals such as lead (Pb), iron (Fe), chromium (Cr), cadmium (Cd), copper (Cu), cobalt (Co), Nickel (Ni) and zinc (Zn) in developing countries is a major public health problem (1, 2). This has been demonstrated in Uganda, for example, in beef (3, 4), in drinking water (5, 6), street food (7), alcoholic beverages (8, 9), fish (10), food crops grown at dumpsites (11), and in food consumed around Lake Victoria and Lake George (12–14). Compounding this is human activities such as mining, irrational usage of chemicals and poor policies on industrial waste management which only exacerbate the problem (15, 16). In Africa, there is a general absence of legislations clearly designed to mitigate environmental degradation. This only suggests one natural course for the continent: that environmental contamination with heavy metals will worsen.

In the body, essential elements in moderate amounts play a crucial role in cellular functions. Their bioavailability is required for certain enzymes to aid metabolic reactions in cellular systems. Iron for example, once complexed with Cu, helps in electron transport system during ATP metabolism [see Supplementary Information in (17)]. The World Health Organization (WHO) recommends a daily intake of 6 ppm/day for Fe and 1 ppm for Cu in children. For a 70 kg adult, the recommendation is 392 ppm/week for Fe and 245 ppm/week for Cu (18). Excessive human consumption of Cu can disrupt physiological processes in the digestive and excretory systems leading to intestinal ulcerations and tubular necrosis (19, 20). Concentrations of Fe and Cu in beef samples are 184 and 160 ppm, respectively (21). Furthermore, contamination of red meat with heavy metals has been identified as a major public health risk requiring novel strategies to decontaminate meat (22).

Zn, an importance micronutrient, is an essential co-factor in living cells. It is required in maintaining the integrity of cellular structure, and as a regulator of cellular activities associated with strong antioxidant capacity (23, 24). The recommended maximum consumption of Zn is 7 ppm/week for a child (18) and 490 ppm/week for a 70 kg adult (25). The concentration of Zn in beef has been shown to be 127 ppm (21). This level of Zn is excessive when absorbed into the body since Zn suppresses Cu and Fe absorption leading to deficiencies of these elements in cells. As a consequence, ingestion of high Zn concentrations in a diet leads to gastrointestinal disorders and dysregulation of lipid metabolism in the body (26). Co in the form of vitamin B_{12} (26), is usually present at 0.25 ppm on in beef average (21) and acts as an essential nutrient for managing anemia associated with malabsorption of vitamin B_{12} in humans during ulcers (27). Co toxicity mainly leads to cardiovascular, hematological, neurological, and endocrine deficits. (28, 29).

Non-essential elements such as Pb, Cd, Ni and Cr are toxic to the body. Pb exposure for example is associated with gastrointestinal irritation and neurotoxicity in children and adults while chronic exposure may lead to cancer in humans (30, 31). These metals, Cr and Ni for example, arise from tanneries and from black smith industry, respectively, in Uganda. WHO recommends a tolerable intake of 0.025 ppm/week for Pb (32), a change from a previous permissible limit of 1.75 ppm/week for a 70 kg adult (18). Cd is a carcinogenic agent known to induce some form of cancer (33). This includes