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Assessment of the Presence of Selected Heavy Metals and their Concentration Levels in Fresh and Grilled Beef/Guinea Fowl Meat in the Tamale Metropolis, Ghana

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ABSTRACT

Contamination of meat by heavy metals is a serious threat because of their toxicity and bioaccumulation. These metals come from or are released into the environment and often have direct physiological toxic effects as they are stored or incorporated in tissues, sometimes permanently. This is the first study that reports on the presence and concentration of selected heavy metals in grilled and fresh beef/guinea fowl meat in the Tamale Metropolis of Ghana. The levels of manganese (Mn), zinc (Zn), copper (Cu) and lead (Pb) in fresh and grilled beef samples ranged from 0.19-0.80, 1.45-2.24, 0.05-0.09 and 0.63-1.63 mg kg^{-1}, respectively with the exception of cadmium (Cd), which was not detected in the beef samples. Heavy metals concentration in the fresh and grilled beef samples did not differ significantly ($p>0.05$) from each other. In absolute terms, Mn, Zn and Cu were generally higher in fresh beef than grilled beef; Pb was higher in the grilled beef than in the fresh beef. The levels of heavy metals in fresh and grilled guinea fowl meat ranged from 0.28-0.45 mg kg^{-1} for Mn, 0.71-1.39 mg kg^{-1} for Zn, 0.03-0.45 mg kg^{-1} for Cu and 0.41-0.70 mg kg^{-1} for Pb. The Cd was also not detected in the guinea fowl meat samples examined. The concentrations of the heavy metals in the fresh and grilled guinea fowl meat samples were found not to be statistically significant ($p>0.05$). In absolute terms, generally the fresh guinea fowl meat samples had higher concentrations of the heavy metals compared to the grilled guinea fowl meat samples. The concentration of manganese, copper, zinc and cadmium were below the permissible limits with the exception of lead. Therefore beef and guinea fowl meat samples in the Tamale Metropolis can be considered as being safe from the heavy metals examined in this study.

Key words: Beef, concentration, environment, guinea fowl meat, heavy metals

INTRODUCTION

In recent times, one of the fascinating aspects of present day urban social life around the world is the widespread presence of street food and street food vendors. Street vending is an activity that provides employment to many, while providing nutritious, inexpensive and ready-to-eat food to millions of workers (Shekhar, 2010). Some of these foods include grilled/roasted meat. Grilled meat is known to be an important source of vitamins B and trace elements and greatly contributes to the daily intake of these micronutrients (Lombardi-Boccia *et al*., 2005). Heavy metals have been identified in effluents of textile industry, grasses, fishes, aquatic environments, surface sediments and microbes (Jiraungkoorskul *et al*., 2007; Arabani *et al*., 2010; Nwude *et al*., 2011;

Rahouma *et al*., 2013; Tuo *et al*., 2013; Fenta, 2014; Muhammad *et al*., 2014; Wani and Irene, 2014). Fresh, grilled and processed meat samples are expose to a number of contaminants from the environment that may include foodborne pathogens, spoilage microorganisms, heavy metals and many more (Iwegbue *et al*., 2008; Adzitey *et al*., 2010, 2011, 2012a-c, 2013a, b, 2014; Hussain *et al*., 2012; Geck *et al*., 2014). Demirezen and Uruc (2006) reported that contamination with heavy metals is a serious threat, because of their toxicity, bioaccumulation and biomagnifications in the food chain. Hussain *et al*. (2012) also reported that 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 (Hussain *et al*., 2012). These heavy metals which include iron (Fe), chromium (Cr), nickel (Ni), manganese (Mn), zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd), mercury (Hg) etc may arise from the environment, during the manufacturing of goods and/or as a result of human activities.

In Northern Ghana which includes the Tamale Metropolis, beef and guinea fowl meat are widely consumed and serves as a major source of protein to the population. Tamale Metropolis is noted for beef and guinea fowl roasting/grilling on streets especially at night. Metallic mesh used in grilling beef and guinea fowl meat in the Metropolis includes ungalvanized metallic mesh used for building and those from refrigerators. Cattle and guinea fowls sometimes feed on contaminated feed, drink contaminated water and are expose to contaminations from emissions of vehicles. The metallic meshes used in grilling meat, the type of feed and water animals consume and the exposure to environmental emissions suggest that meats in Tamale may be sources of heavy metals. Therefore this study was carried out to determine the presence and concentration of selected heavy metals in grilled and fresh beef and guinea fowl meat in the Tamale Metropolis of Ghana.

MATERIALS AND METHODS

Sample collection: Grilled and fresh beef/guinea fowl meat samples were obtained from 2 meat vendors/grillers in the Tamale Metropolis. These two vendors are located in Tishegu (Alhassan Hotel) and Aboabo (Victory cinema) and are among the most popular places, where people like to buy grilled beef and guinea fowl meat in the Tamale Metropolis. A total of 16 meat samples (four fresh beef, four grilled beef, 4 fresh guinea fowl and four grilled guinea fowl meat) were collected from these vendors. The various meat samples were packed in sterilized plastic bags and transported under 4°C to the laboratory (Council for Scientific and Industrial Research, Water Research Institute, Tamale), where analysis for heavy metals were carried out immediately upon arrival at the laboratory. The study was carried out in the periods of January, 2014 to June, 2014.

Sample preparation and elemental analysis: The determination of manganese (Mn), zinc (Zn), copper (Cu), lead (Pb) and cadmium (Cd) was done using a slightly modified method of AOAC (1995). Briefly, a known quantity of 0.5 g of each meat sample (dried fresh and grilled beef/guinea fowl meat samples) was introduced into a digestion flask. The 2.5 mL of sulphuric acid (H_2SO_4) was added into it and digested. After digestion, 10 mL of HNO_3 was added in drops until a clear solution was obtained. The content was heated for 1 h. The content of the flask was filtered into a 50 mL volumetric flask and made up to the mark with distilled water. Content was heated 15 min, allowed to cool and filtered. Determination of Mn, Zn, Cu, Pb and Cd were made directly on each of the final solutions using the Atomic Absorption Spectroscopy (AAS).

Data analysis: Data collected were subjected to Analysis of Variance (ANOVA) using Genstat Statistical Software (4th edition) and differences were between means declared at 0.05 significant level.

RESULTS

The type of heavy metals and their concentration in the fresh and grilled beef samples examined is presented in Table 1. The study revealed the presence and absence of heavy metals in both fresh and grilled beef samples. The concentration of the heavy metals varied among the beef samples examined. Heavy metals quantified in the beef samples were statistically insignificant ($p>0.05$) among samples as shown in Table 1. The levels of manganese (Mn), zinc (Zn), copper (Cu) and lead (Pb) ranged from 0.19-0.80, 1.45-2.24, 0.05-0.09 and 0.63-1.63 mg kg^{-1}, respectively. Cadmium (Cd) was not detected in the fresh and grilled beef samples.

The result of the concentrations of the various heavy metals examined in fresh and grilled guinea fowl meat samples is presented in Table 2. Similar to beef samples, some heavy metals like Mn, Zn, Cu and Pb were present in the guinea fowl meat samples while Cd was absent. The concentrations of the heavy metals vary from 0.28-0.44 mg kg^{-1} for Mn, 0.71-1.39 mg kg^{-1} for Zn, 0.03-0.44 mg kg^{-1} for Cu and 0.41-0.70 mg kg^{-1} for Pb. Cadmium was not detected in the fresh and grilled guinea fowl samples. There were no significant differences ($p>0.05$) among the fresh and grilled guinea fowl meat samples (Table 2).

DISCUSSION

Heavy metals in general play a role in normal physiological processes but can accumulate to toxic levels, particularly in certain organs. Heavy metals may enter the human body through food, water, air or absorption through the skin (Alissa and Ferns, 2011; Tchounwou *et al*., 2012). This study aimed at identifying the presence and concentration of some heavy metals in fresh and grilled beef/guinea fowl meats sold in the Tamale Metropolis of Ghana. Manganese (Mn), zinc (Zn), copper (Cu) and lead (Pb) were all present in the meat samples examined. The concentration of heavy metals in the meat samples (fresh and grilled beef/guinea fowl meat) did not differ significantly ($p>0.05$) from each other (Table 1 and 2). Therefore we report the presence of the heavy metals in

Table 1: Concentrations of heavy metals in fresh and grilled beef in the Tamale, Ghana

Metals (mg kg^{-1})	FBT	GBT	FBA	GBA	SED	p-values
Mn	0.80	0.19	0.28	0.32	0.42	0.54
Zn	2.24	1.51	1.62	1.45	0.74	0.71
Cu	0.05	0.05	0.08	0.09	0.01	0.14
Pb	0.63	1.63	1.38	1.62	0.27	0.06
Cd	0.00	0.00	0.00	0.00	ND	ND

FBT: Fresh beef obtained from Tishegu, GBT: Grilled beef obtained from Tishegu, FBA: Fresh beef obtained from Aboabo, GBA: Grilled beef obtained from Aboabo, ND: Not done, Mn: Manganese, Zn: Zinc, Cu: Copper, Pd: Lead and Cd: Cadmium

Table 2: Concentrations of heavy metals in fresh and grilled guinea fowl meat in Tamale, Ghana

Metals (mg kg^{-1})	FGT	GGT	FGA	GGA	SED	p-values
Mn	0.29	0.28	0.31	0.44	0.07	0.23
Zn	1.39	0.88	0.71	0.79	0.27	0.19
Cu	0.10	0.08	0.44	0.03	0.26	0.44
Pb	0.70	0.59	0.42	0.41	0.38	0.85
Cd	0.00	0.00	0.00	0.00	ND	ND

FGT: Fresh guinea fowl meat obtained from Tishegu, GGT: Grilled guinea fowl meat obtained from Tishegu, FGA: Fresh guinea fowl meat obtained from Aboabo, GGA: Grilled guinea fowl meat obtained from Aboabo, ND: Not done, Mn: Manganese, Zn: Zinc, Cu: Copper, Pd: Lead and Cd: Cadmium

absolute terms in this study. The presence of Mn, Zn, Cu and Pb in all the meat samples suggests that cattle and guinea fowl in Tamale were exposed to, fed on feed or drunk water that contained these metals.

Cadmium was not detected in all the meat samples collected from Tishegu as shown in Table 1 and 2. Thus fresh and grilled beef/guinea fowl meat samples examined did not contain Cd or Cd was present, but in very low level beyond detectable limit. Alissa and Ferns (2011) showed that Cd accumulates within the kidney and liver over long time. In this study we examined muscle samples and not kidney or liver samples. Mariam *et al.* (2004) found cadmium concentrations in mutton to be 0.41 mg kg^{-1}, beef to be 0.42 and 0.49 mg kg^{-1} for poultry. Anonymous (2014) long-term exposure to Cd is associated with renal dysfunction and high exposure can lead to obstructive lung disease and lung cancer. Cadmium also causes neurological diseases, cancers and damage to the liver, placenta, kidneys, lungs, brain and bones (Alissa and Ferns, 2011).

The highest concentration of Mn for beef was found in fresh beef (0.80 mg kg^{-1}) collected from Tishegu (FBT) and the least was found in grilled beef (0.19 mg kg^{-1}) collected from Tishegu (GBT). For guinea fowl meat, the highest concentration of Mn was 0.44 mg kg^{-1} from grilled guinea fowl meat collected from Aboabo (GGA) and the least was 0.28 mg kg^{-1} from grilled guinea fowl meat collected from Tishegu (GGT). Long-term exposure to excess levels of Mn may result in iron-deficiency anaemia and increased manganese intake impairs the activity of copper metallo-enzymes (Blaurock-Busch, 2002). Furthermore, 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 Uruc, 2006). The Mn concentration of turkey meat, chicken meat and chicken gizzard tanged from 0.01-1.37 mg kg^{-1} (Iwegbue *et al.*, 2008). The Mn concentration obtained in this study (0.19-0.80 mg kg^{-1}) was within the range obtained by Iwegbue *et al.* (2008).

The highest Zn concentration for beef was 2.2 mg kg^{-1} (FBT, fresh beef from Tishegu) and the least was 1.45 mg kg^{-1} (GBA, grilled beef from Aboabo). In guinea fowl meat, the highest concentration was 1.39 mg kg^{-1} (FGT, fresh guinea fowl meat from Tishegu) and the least was 0.71 mg kg^{-1} (FGA, fresh guinea fowl meat from Aboabo). Zinc is an essential trace element for the livelihood of animals and humans. Zinc deficiency has been associated with loss of appetite, anemia, slow wound healing, abnormal taste, depressed growth, altered cognition, diarrhea and hair loss (Anonymous, 2014). Iwegbue *et al.* (2008) found Zn concentrations to range between 4.95-48.23, 6.12-33.21 and 10.19-37.03 mg kg^{-1} for turkey meat, chicken meat and chicken gizzard, respectively. In this study we found lower concentrations of Zn, that is, between 1.45-2.24 mg kg^{-1} for fresh and grilled beef samples and 0.71-1.39 mg kg^{-1} for fresh and grilled guinea fowl meat.

The highest concentration of Cu for beef was found in grilled beef (0.09 mg kg^{-1}) collected from Aboabo (GBA) and the least was 0.05 mg kg^{-1} and was found in FBT (fresh beef from Tishegu) and GBT (grilled beef from Tishegu). With regards to guinea fowl meat, the highest concentration of Cu was 0.44 mg kg^{-1} from fresh guinea fowl collected from Aboabo (FGA) and the least was 0.03 mg kg^{-1} from grilled guinea fowl collected from Aboabo (GGA). Copper is an essential substance to human life but in high doses it can cause anemia, brain, liver and kidney damage and stomach and intestinal irritation (Agency for Toxic Substances and Disease Registry, ATSDR., 2004). Iwegbue *et al.* (2008) reported the average Cu levels to be between 0.01-3.36 mg kg^{-1} for turkey meat, 0.01-5.15 mg kg^{-1} for chicken meat and 0.46-2.55 mg kg^{-1} for chicken gizzard. This study found a range of 0.05-0.09 mg kg^{-1} for grilled and fresh beef samples and 0.03-0.44 mg kg^{-1} for fresh and grilled guinea fowl meat. The values of Zn in this study fell within the values obtained for turkey and chicken meats in the study by Iwegbue *et al.* (2008). The concentration of Zn in chicken gizzard (Iwegbue *et al.*, 2008) was higher than that of this study.

Lead (Pb) concentration was found to be highest in grilled beef collected from Tishegu (1.63 mg kg^{-1}) for beef and in fresh guinea fowl meat collected from Tishegu (0.70 mg kg^{-1}) for guinea fowl. The least were 0.63 mg kg^{-1} (FBT, fresh beef from Tishegu) for beef and 0.41 mg kg^{-1} for guinea fowl meat (GGA, grilled guinea fowl meat from Aboabo). Lead is toxic if it is consumed in amounts which exceeds the threshold and can cause acute and chronic poisoning symptoms (Nawrot *et al*., 2010). Lead is known to cause damage to the bones, brain, blood, kidneys and thyroid gland when it exceeds the limit for a longer time (Nawrot *et al*., 2010). Mariam *et al*. (2004) reported mean levels of lead to be 2.18 mg kg^{-1} for beef, 4.25 mg kg^{-1} for mutton and 3.15 mg kg^{-1} for poultry. The levels found in this study were lower than the values are reported by Mariam *et al*. (2004).

The maximum permissible hygiene limits according to the Codex Alimentorum, Slovak Republic No. 981/1996 for Cd, Pb, Cu, Zn in muscle is 0.1, 0.4, 5 and 60 mg kg^{-1}, respectively (Korenekova *et al*., 2002). Permissible limit for Mn in meat, poultry, fish and eggs range from 0.10-3.99 mg kg^{-1} (Koplan, 2000). Pb, Mn, Zn and Cu concentrations in the grilled and fresh beef/guinea fowl meat samples in this study were below the permissible limit as reported by Koplan (2000) and Korenekova *et al*. (2002). The Pb concentration for the fresh and grilled beef/guinea fowl meat samples were beyond the permissible limit as reported by Korenekova *et al*. (2002). Thus consumers of beef and guinea fowl meats in the Tamale Metropolis have to be aware of the possible Pb hazard they are expose to.

CONCLUSION

Manganese (Mn), zinc (Zn), copper (Cu) and lead (Pb) were present in fresh and grilled beef/guinea fowl meat samples sold in Tamale, Ghana. Cadmium (Cb) was absent in fresh and grilled beef/guinea fowl meat samples. The Mn, Zn, Cu and Pb ranged from 0.19-0.80, 1.45-2.24, 0.05-0.09 and 0.63-1.63 mg kg^{-1}, respectively for fresh and grilled beef. Mn, Zn, Cu and Pb ranged from 0.71-1.39, 0.03-0.45 and 0.41-0.70 mg kg^{-1}, respectively for fresh and grilled guinea fowl meats. The concentrations of Mn, Zn, Cu and Pb in the beef and guinea fowl meat samples were below permissible limit except Cb.

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