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Original Research

Estimation of Heavy Metal Contents in the Retailed Meat Products in Zagazig City, Egypt

Alaa Eldin M.A. Morshdy[1], Reem H. Abdelhamid[1], Ahmed E. Tharwat[1], Wageh S. Darwish[1*], Elshimaa A.A. Nasr[2]

[1]Food Control Department, Faculty of Veterinary Medicine, Zagazig University, 44519 Zagazig, Egypt.

[2]Educational Veterinary Hospital, Faculty of Veterinary Medicine, Zagazig University, 44519 Zagazig, Egypt.

***Correspondence**
Corresponding author: Wageh S. Darwish
E-mail address: wagehdarwish@gmail.com

Abstract

A significant source of high quality animal protein, vitamins, and minerals are meat products. However, during the course of production or during the life of the animals used to produce the meat for these businesses, heavy metals may be present in meat products. The amount of dangerous metals like lead (Pb), cadmium (Cd), and trace elements like copper (Cu) and zinc (Zn) that remain in such items is obviously unknown. In order to determine the residual Pb, Cd, Cu, and Zn concentrations in three meat products, pasterma, luncheon and sausage, this study was carried out. Additionally, for Egyptian consumers, estimated daily intakes (EDI) and potential health concerns associated with consuming such meat products were calculated. The obtained results showed that the evaluated products were contaminated with the tested metals at varying rates. The highest Cd, Cu, and Zn contents and contamination levels were generally seen in pasterma. While Pb contamination rates at luncheons were highest. The maximum allowable limits for heavy metal residues were not exceeded in any samples. The calculated estimated daily intakes, hazard ratio, and hazard index did not identify any potential concerns related to Egyptian consumers' consumption of such meat products.

KEYWORDS
Heavy metals, Health hazards, Meat products, Egypt

INTRODUCTION

An important source of animal-derived protein, vital amino acids, and trace elements is meat products. Additionally, meat products have a distinctive taste and flavor that make them highly sought-after, especially by young and old people. Pasterma, luncheon and sausage are only a few of the meat products that have been created and introduced to supermarkets and butcher shops (El Bayomi *et al*., 2018; Morshdy *et al*., 2019). Heavy metals are just one of the many xenobiotics that animals that produce meat are exposed to throughout their lives (Darwish *et al*., 2010a, b). Both animal health and consumer safety are significantly impacted by such contaminants (Morshdy *et al*., 2013; Darwish *et al*., 2015; Darwish *et al*., 2018; El Bayomi *et al*., 2018; Morshdy *et al*., 2019; Morshdy *et al*., 2022) and several types of fish (Morshdy *et al*., 2019) were among the research that looked at the presence of heavy metal residues in food of animal origin in Egypt. Less attention, however, had been paid to the examination of heavy metal deposits in animal products.

The bioaccumulation and biomagnification properties of heavy metals like lead (Pb), cadmium (Cd), and trace elements like zinc (Zn) and copper (Cu) are well known. Numerous toxicological effects on humans could result from exposure to such metals (Thompson and Darwish, 2019). According to Darwish *et al*. (2016), lead poisoning is to blame for a number of child fatalities worldwide. In addition to being toxic to the kidneys, the digestive system, and other organs, Pb can also be neurotoxic (Cunningham and Saigo, 1997). Cd is yet another toxic substance that can reach humans via the food chain. According to the US Environmental Protection Agency (IARC, 2016), cadmium is a category B1 carcinogen. Additionally, Cd is predominantly responsible for the itai-itai disease, which is characterized by renal failure and osteomalacia (Nishijo *et al*., 2017). Furthermore, long-term damage to many organs, such as the liver, kidneys, testes, breast, and nervous system, has been linked to exposure to low levels of Cd (Elhelaly *et al*., 2022).

Copper is an essential element that has a profound impact on the biochemistry and physiology of living creatures as a co-factor for many enzymes. Furthermore, Cu is essential for cellular respiration. The organelles of the cell could suffer oxidative damage from prolonged exposure to Cu, though (Darwish *et al*., 2014). Zn serves as a crucial trace element for the catalytic activity of more than 100 enzymes in the body. Zn is also required for the regulation of the gene expression of many different cell components. Zn is also necessary for maintaining the cell wall. Many underdeveloped countries experience considerable zinc shortage, which among other health issues can result in anemia, weakened immunity, hypogonadism, and dwarfism. For human consumption, meat products are recognized as a major source of zinc (Zn) (Roohani *et al*., 2013; Pogorzelska-Nowicka *et al*., 2018).

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Given the aforementioned information, this study sought to estimate the residual Pb, Cd, Cu, and Zn content in three meat products, including pasterma, luncheon, and sausage sold in Egypt. Additionally, the health risks related to consuming such products were computed.

MATERIALS AND METHODS

Collection of samples

Sixty samples of meat products were collected from Sharkia governorate, Egypt. Pasterma, luncheon, and sausage samples (20 of each) were gathered from grocery stores and retail marketplaces in Zagazig, Egypt. In order to estimate heavy metals, 50 g of each sample were transported chilled to the Meat Hygiene Laboratory at the Food Control Department, Faculty of Veterinary Medicine, Zagazig University, Egypt.

Preparation and extraction of samples

One gram of each sample was added to 10 ml of a digestion solution made up of 3 parts HNO_3 55% and 2 parts $HClO_4$. The mixture was thoroughly homogenized and left at room temperature overnight. After that, the mixture was shaken for three hours in a water bath that was heated to 70°C (El-Ghareeb *et al*., 2019).

Heavy metal measurements

Using hollow cathode lamps with an air-acetylene flame, the atomic absorption spectrophotometer (Shimadzu AAS 6800, Shimadzu, Japan) was used to measure the metal concentrations of Pb, Cd, Cu, and Zn. The amounts of the detected heavy metals were determined using standard curves that were developed for each of the analyzed metals. The results were recorded on a wet weight (ww) basis and displayed as ppm.

Quality assurance

The accuracy of the analysis was established by measuring the samples twice and using the recognized reference material IAEA-142/TM (muscle homogenate), Vienna, Austria. The average recoveries for the metals under investigation ranged from 95 to 105 percent. The recovered concentrations of the certified samples were within 3% to 5% of the certified limits. All of the tools and supplies used in the study were cleaned with weak nitric acid to avoid external contamination with heavy metals.

Dietary intakes of heavy metals

Calculations from the US EPA's 2010 Human Health Evaluation Manual were used to determine the tested heavy metals' estimated daily intake (EDI) values (µg/kg/day):

$$EDI = C*FIR/BW$$

The meat products ingestion rate in Egypt was set at 87.5 g/day (FAO, 2003); C refers to the concentration of the tested metals (in ppm ww); and BW represents the estimated average weight in Egypt, which was set at 70 kg for adults.

Health risk assessment

The non-cancer risks resulted from consumption of toxic metal-contaminated meat products among the Egyptians were calculated using the US EPA (2010) recommendations. The EDI was compared to the recommended reference doses (RfD) (0.001 mg/kg/day for Cd, 0.004 mg/kg/day for Pb, and 0.3 mg/kg/day for Zn) in order to compute the hazard ratio (HR) (US EPA, 2010).

$$HR = EDI/RfD*10^{-3}$$

A hazard index (HI) can be created by adding the hazard ratios to estimate the health hazards posed by combined pollutants.

$$HI = \sum HR_i$$

where *i* represents each metal

A result of one or less shows no risk, whereas a value of more than one suggests a potential harm to human health.

Statistical analysis

The one-way ANOVA procedure of SPSS v.23 (SPSS Inc., Chicago, Illinois, The USA) was used to analyze the data, followed by the Tukey-Kramer test (JMP) for statistical comparisons ($p<0.05$).

RESULTS AND DISCUSSION

Occurrence of heavy metal residues in the examined samples

The obtained results in the present study revealed detection of Pb in luncheon, pasterma and sausage at 90%, 80%, and 70%, respectively. There were no significant differences in the residual Pb concentrations among the examined meat products. The average concentrations (ppm) of Pb were 0.01±0.001, 0.01±0.002, and 0.01±0.001 in the examined luncheon, pasterma, and sausage, respectively (Fig. 1). In agreement with the obtained results of the present investigation, the retailed meat products in Spain had a relatively similar Pb concentration (0.007 ppm) (González-Weller *et al*., 2006). While higher Pb residues were found in sausage sold in Iran (0.16 ppm) (Abedi *et al*., 2011). Similar to this, it was discovered that South Italian swine meat products, including mortadella, baked ham, raw ham, cured sausage, salami and würstel, had increased Pb contents, ranging from 0.22 to 0.ppm (Barone *et al*. 2021). In Egypt, Pb was detected at higher levels (ppm) in the retailed meat products in Sharkia as in pasterma (0.15±0.02), sausage (0.11±0.01), and luncheon (0.08±0.01) (Elhelaly *et al*., 2022).

In the current investigation, Cd was detected in all examined pasterma and luncheon samples, and 90% of sausage samples. Pasterma had the highest Cd residues (ppm) among the examined beef meat products (0.03±0.01), followed by luncheon (0.009±0.001), and sausage (0.001±0.0003), respectively (Fig. 2). Comparatively, in South Italy, hog meat products have Cd values of 0.01-0.03 ppm, according to Barone *et al*. (2021). Lower Cd residues (2.2-13.5 ppb) were found in Iranian sausage that was sold commercially (Abedi *et al*., 2011). In Egypt, the meat products with the highest Cd residues were pasterma (0.08±0.009), sausage (0.05±0.005), and luncheon (0.04±0.006) (Elhelaly *et al*. 2022).

Similar to Cd, all examined pasterma, and luncheon samples contained Zn residues, but Zn was detected in sausage samples at 70%. Pasterma had the highest Zn residual concentration, followed by luncheon, and sausage at 0.26±0.02, 0.18±0.006, and 0.09±0.03 ppm, respectively (Fig. 3). All of the samples of meat products that were evaluated and sold in Egypt likely contained zinc. According to Elhelaly *et al*. (2002), the maximum Zn level (ppm) was found in pasterma (20.94 0.53), followed by sausage (15.21 0.37) and luncheon (14.06 0.41). Additionally, the swine meat products commercialized in Italy included Zn residues between 5.71 and 7.32 ppm (Barone *et al*., 2021). In addition, retail meat in Nigeria was found to contain Zn (121.27 7.45 ppm) (Ihedioha *et al*., 2014).

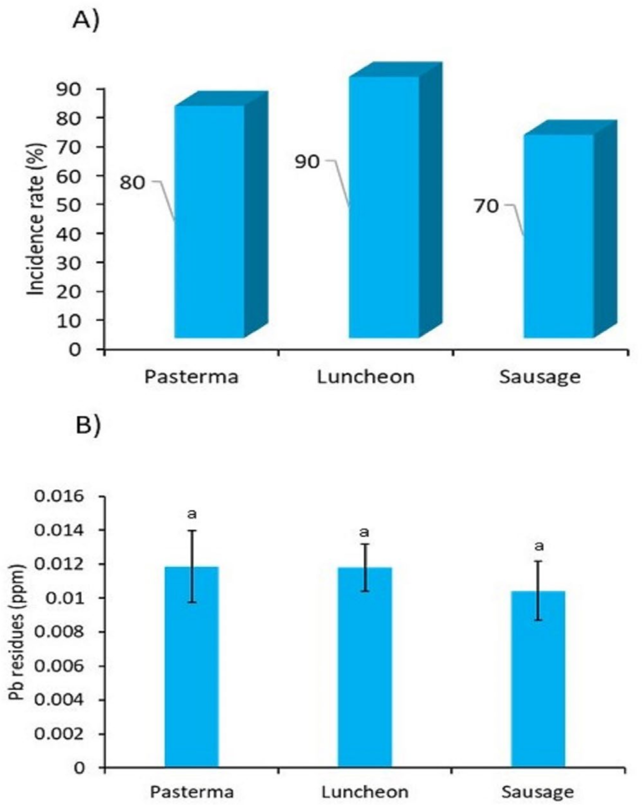

Fig. 1. Lead (Pb) residues in the examined meat products in the present study. A) Incidence rate (%). B) Residual concentrations (ppm) of Pb in the examined pasterma, luncheon, and sausage. Values represent means±SE for the tested samples. Columns with different letter are significantly different at P< 0.05.

Copper was detected in all pasterma samples, and at 80% of the examined sausage, and luncheon samples. Luncheon had the highest Cu residual concentrations, followed by pasterma, and sausage, respectively at 0.02±0.01, 0.01±0.001, and 0.0003±0.0001 ppm, respectively (Fig. 4). All of the tested meat product samples contained copper, with levels ranging from 1.24 to 4.13 in luncheon, 2.59 to 8.33 ppm in pasterma, and 2.24 to 4.36 ppm in banger sold in Egypt (Elhelaly *et al*., 2022). Internationally, Barone *et al*. (2021) revealed that the pork meat products sold in Italy had higher Cu contents (1.08-1.21 ppm).

Natural occurrences of heavy metals in the environment allow them to enter the bodies of animals through tainted feed and water. Except for mercury, the characteristics of heavy metals include bioaccumulation, biomagnification, and resilience to heat treatment. Heavy metal contamination in meat products is also largely caused by the usage of contaminated raw materials (Morshdy *et al*., 2013, 2019; Thompson and Darwish, 2019).

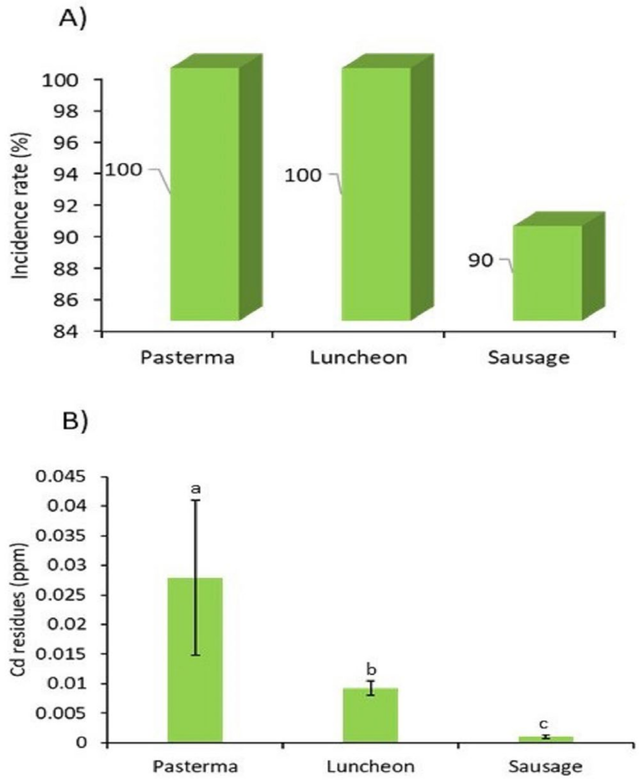

Fig. 2. Cadmium (Cd) residues in the examined meat products in the present study. A) Incidence rate (%). B) Residual concentrations (ppm) of Cd in the examined pasterma, luncheon, and sausage. Values represent means±SE for the tested samples. Columns with different letter are significantly different at P< 0.05.

Dietary intakes and human health risk assessment

In accordance with the established maximum allowed limits (MPL) for Pb (0.1 ppm) (EC, 2006), all beef products under analysis contained residual Pb contents (Table 1). According to Darwish *et al*. (2016) and the EFSA (2010), excessive consumption of Pb-contaminated foods may have toxicological consequences on the body, such as cytotoxicity, mutagenicity, carcinogenicity, disturbances of the central nervous system, and hemoglobin synthesis. Calculating the EDI of Pb in the examined samples, the results revealed that the EDI values ranged from 0.012 to 0.014. The World Health Organization set 3.5 g/kg/day as the provisional tolerated daily intake (PTDI) for lead (Pb) (WHO, 2010). The HR values for Pb exposure from consuming meat products were also evaluated, and the results indicated values considerably below one, indicating that there is no potential health risks associated with doing so. It's likely that Darwish *et al*. (2015) reached the conclusion that there is no risk of Pb exposure from consuming offal and meat from cattle and sheep in Egypt.

Similar to Pb, the investigated samples' Cd residual levels were below the MPL (0.05 ppm) specified by EC 2006 (Table 1).

Table 1. Estimated daily intakes and risk assessment of Pb, Cd, Cu, and Zn due to consumption of pasterma, luncheon, and sausage in Egypt.

	Pb			Cd			Cu			Zn			
	%	EDI	HR	%	EDI	HR	%	EDI	HR	%	EDI	HR	HI
Pasterma	0	0.01	0.00	0	0.03	0.03	0	0.02	NA	0	0.32	0.00	0.04
Luncheon	0	0.01	0.00	0	0.01	0.01	0	0.03	NA	0	0.22	0.00	0.02
Sausage	0	0.01	0.00	0	0.00	0.00	0	0.00	NA	0	0.11	0.00	0.01

% refers to percentage of samples exceeding the established maximum permissible limits (ppm) 0.1 for Pb, 0.05 for Cd, 5 for Cu, and 50 for Zn (EC, 2006).

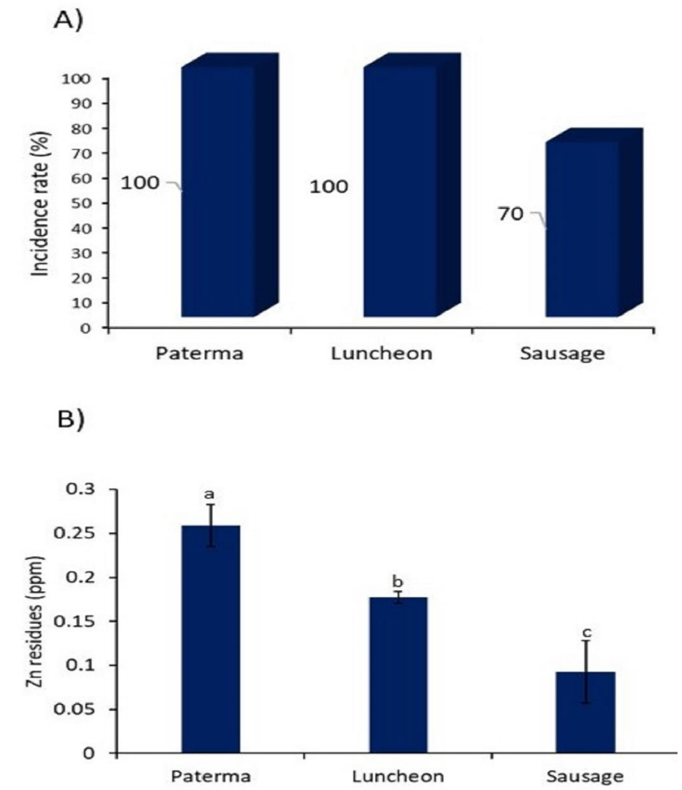

Fig. 3. Zinc (Zn) residues in the examined meat products in the present study. A) Incidence rate (%). B) Residual concentrations (ppm) of Zn in the examined pasterma, luncheon, and sausage. Values represent means±SE for the tested samples. Columns with different letter are significantly different at P< 0.05.

According to Morshdy *et al.* (2013), eating foods contaminated with Cd increases the risk of developing nephropathy, renal failure, brittle bones, and cancer. The pasterma had the highest EDI of Cd (0.034 g/kg/day). The PTDI for Cd (1 g/kg/day) was met by the recorded EDI of Cd for all products under examination (WHO, 2010). Furthermore, none of the computed HR values for Cd in the examined samples surpassed one, demonstrating that consuming such chicken products would not be hazardous to the general public's health. In line with the results of the present investigation, Elhelaly *et al.* (2022) reported that Cd residues in meat products in Egypt would not endanger Egyptian consumers. Darwish *et al.* (2015) hypothesized that eating sheep and cow offal in Egypt may raise the risk of Cd exposure.

Each sample of beef product that was analyzed contained residual Zn levels that were under the defined MPL (50 ppm) (EC, 2006). Additionally, the PTDI (1 g/kg/day) was not exceeded by the Zn EDI for any of the samples. In the samples that were analyzed (Table 1). Zn's computed HR values were well below one, demonstrating that consuming such goods would not pose any serious health risks. South Korea and Italy both reported consuming similar amounts of zinc (Licata *et al.*, 2004; Khan *et al.*, 2014). Zn is a trace element that is essential for the proper operation of the body's systems, but too much of it can cause nausea, insomnia, and neurodegenerative diseases (Faa *et al.*, 2008).

In all the meat product samples that were analyzed, the copper concentration did not exceed the MPL (5 ppm) that was established (EC, 2006) (Table 1). In the tested pasterma, luncheon and sausage, the recorded EDI of Cu did not surpass the PTDI of Cu (0.5 g/kg/day) (WHO, 2010). The RfD values for copper are unknown, hence the HR of copper was not important to this inquiry. Unlikely, Poland reported having a high Cu intake (Sujka *et al.*, 2019). Copper is necessary for the healthy operation of several enzymes in the body, but excess copper can result in hyperthyroidism, allergic reactions, and hepatic cirrhosis (Darwish *et al.*, 2014).

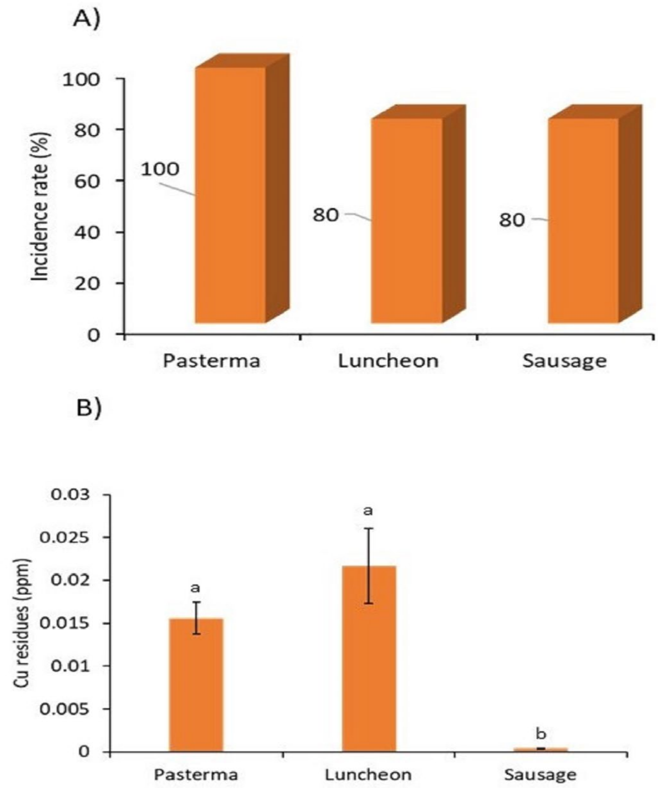

Fig. 4. Copper (Cu) residues in the examined meat products in the present study. A) Incidence rate (%). B) Residual concentrations (ppm) of Cu in the examined pasterma, luncheon, and sausage. Values represent means±SE for the tested samples. Columns with different letter are significantly different at P< 0.05.

Overall values below one were obtained when the HI for mixed contaminants in the tested meat products was calculated, demonstrating that Egyptian consumers would not be at risk for health issues from ingesting such items.

CONCLUSION

Pb, Cd, Cu, and Zn are found in all the analyzed samples at various quantities. The detected metals' residual concentrations in the samples under examination are below the recommended MPL. Additionally, the computed HR and HI for all of the examined samples for the measured metals are not exceeding the value of one, demonstrating that consuming such meat products would not be harmful to human health.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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