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Original Research

Heavy Metal Content in Chicken Meat Products: A Health Risk Assessment Study

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Abstract

There is an increasing demand for chicken meat products due to their high nutritive value, specific aroma and flavor, and cheap price compared to red meat. However, there is a clear lack of information on the residual content of toxic metals such as lead (Pb), cadmium (Cd), mercury (Hg), and trace elements such as zinc (Zn), and copper (Cu) in such products. Therefore, this study was undertaken to estimate the residual contents of Pb, Cd, Hg, Zn, and Cu in five chicken meat products including chicken burger, chicken fillet, chicken luncheon, chicken nuggets, and chicken panne. Moreover, estimated daily intakes (EDI), and the potential health risks of heavy metals due to consumption of such meat products were calculated for Egyptian adults and children. The achieved results indicated no detection of Hg in any sample. However, the other measured elements were detected in all examined chicken meat product samples at variable concentrations. The chicken burger had the highest metal concentrations. Several samples had higher Pb and Cd levels than the set maximum permissible limits. However, the calculated EDI, hazard ratio, and hazard index revealed no potential risks associated with the consumption of such chicken meat products among Egyptian adults and children.

KEYWORDS
Heavy metals, health hazards, chicken meat products, Egypt.

INTRODUCTION

Chicken meat represents an important animal-derived protein, essential amino acids, and trace elements. In addition, chicken meat contributes largely as a relatively cheap alternative source for red meat, which faces a significant shortage in Egypt. Due to the fast progress in the field of food processing and technology, several chicken meat products were developed and released into the chicken meat markets such as chicken burgers, chicken fillets, chicken luncheon, chicken nuggets, and chicken panne. Such products are characterized by their unique aroma and flavor which attracts consumers, particularly children (El Bayomi *et al*., 2018; Morshdy *et al*., 2019). Different poultry species, such as chicken is exposed to a vast array of xenobiotics during their life such as antibiotics, hormones, and heavy metals. Such pollutants have significant effects on both animal health and consumers' safety (Darwish *et al*., 2018; El Bayomi *et al*., 2018). Several studies investigated the occurrence of hormones and antibiotic residues in chicken meat and meat products, however, the investigation of heavy metal residues in chicken meat products had received less attention (Donoghue, 2003; Kadim *et al*., 2010).

Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and trace elements such as zinc (Zn), and copper (Cu) are characterized by their bioaccumulation and biomagnification nature. Human exposure to such metals might lead to several toxicological implications (Thompson and Darwish, 2019). Lead intoxication is to blame for several child fatalities worldwide (Darwish *et al*., 2016). Pb can also be neurotoxic and harm the digestive system, kidneys, and other organs (Cunningham and Saigo, 1997). Another poisonous element that can enter humans through the food chain is Cd. Cadmium was categorized by the US Environmental Protection Agency as a group B1 carcinogen (IARC, 2016). Additionally, the itai-itai disease, which is characterized by renal failure and osteomalacia, is primarily brought on by Cd (Nishijo *et al*. 2017). Additionally, prolonged exposure to low levels of Cd has been associated with harm to numerous organs, including the liver, kidneys, testes, breast, and nervous system (Elhelaly *et al*., 2021). Mercury (Hg) is another toxic metal that was commonly used as antiparasitic, antiseptic, in dental medicine, and gold mining (Ozuah, 2000). However, prolonged exposure to Hg was associated with severe neurological disorders or what is called Minamata disease (Ekino *et al*., 2007).

More than 100 enzymes in the body use Zn as a critical trace element for their catalytic activities. The regulation of the gene expression of numerous cell components also depends on Zn. Additionally, Zn is crucial for maintaining the cell wall. Zinc deficiency is a significant issue in many developing nations and can cause anemia, lowered immunity, hypogonadism, and dwarfism, among other health problems. Chicken meat products are regarded as a key source of Zn for human consumption (Pogorzelska-Nowicka *et al*., 2018; Roohani *et al*., 2013). As a co-factor for various enzymes, Cu is a necessary element that has significant effects on the biochemistry and physiology of living species. Additionally, Cu is a crucial component of cellular respiration. However, prolonged exposure to Cu may cause oxidative damage to the organelles of the cell (Darwish *et al*. 2014).

In sight of the previous facts, this study aimed to an estimation of the residual content of Pb, Cd, Hg, Zn, and Cu in five chicken meat products including chicken burger, fillet, luncheon, nuggets, and panne retailed in Egypt. In addition, health risks associated with the consumption of such products were calculated.

MATERIALS AND METHODS

Collection of samples

The samples included a chicken burger, fillet, luncheon, nuggets, and panne (20 of each). Samples were collected from retail markets and grocery stores in Zagazig city, Egypt during August to December 2021. Fifty grams from each sample were transferred cooled in plastic falcon tubes to the laboratory of Meat Hygiene, Food Control Department, Faculty of Veterinary Medicine, Zagazig University for heavy metal extraction.

Sample preparation and extraction

A 10 ml from sample digestion solution that consists of 3 parts of HNO3 55% and 2 parts of HClO4 was added to one gram from each sample. The mixture was well homogenized and kept overnight at room temperature. The mixture was then placed at a heated water bath (70ºC) with shaking for 3 h (El-Ghareeb *et al*., 2019).

Heavy metal measurements

The atomic absorption spectrophotometer (Shimadzu AAS 6800, Shimadzu, Japan) was used to quantify the metal concentrations of Pb, Cd, Zn, and Cu using hollow cathode lamps with an air-acetylene flame. While hydride generation/cold vapor atomic absorption spectroscopy was used to evaluate Hg concentrations (Shelton, CT, USA). Based on standard curves created for each of the analyzed metals, the concentrations of the detected heavy metals were calculated. A wet weight (ww) basis was used to record the results, which were presented as µg/g.

Quality assurance

By measuring the samples twice and using the approved reference material IAEA-142/TM (muscle homogenate), Vienna, Austria, the correctness of the analysis was validated. The examined metals had average recoveries that varied from 95 to 105 percent. The certified samples' recovered concentrations were within 3% to 5% of the certified levels. To prevent external contamination with heavy metals, diluted nitric acid was used to wash all of the items and equipment used in the analysis.

Dietary intakes of heavy metals

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

EDI = C*FIR/BW

Where C represents the concentration of the tested metal in the sample (in µg/g ww); FIR represents the food ingestion rate in Egypt, which was calculated to be 40.54 g/day for chicken meat products (FAO, 2003); and BW represents the estimated average weight in Egypt, which was set at 70 kg for adults, and 30 kg for children.

Health risk assessment

Using the recommendations of the US EPA (2010), the non-cancer risks related to the intake of metal-contaminated chicken meat products among the Egyptian population were determined. In order to calculate the hazard ratio (HR), 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) (US EPA, 2010).

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

The hazard ratios can be summed to calculate a hazard index (HI) for estimation of the health risks associated with mixed contaminants.

$HI = \sum HR_i$

where i represents each metal

A potential risk to human health is indicated if the HR and/or HI value is greater than one, whereas a result of one or less indicates no risk.

Statistical analysis

For statistical comparisons, the Tukey-Kramer HSD difference test (JMP) (SAS Institute, Cary, NC, USA) was applied ($p < 0.05$).

RESULTS AND DISCUSSION

Residual concentrations of heavy metals in chicken meat products

The recorded results of the current investigation indicated no detection of Hg in any sample. However, Pb was detected in all examined chicken meat product samples. Among the examined chicken meat products, the burger had significantly ($p < 0.05$) the highest Pb content (µg/g ww) (0.86 ± 0.15), followed by fillet (0.73 ± 0.06), pane (0.44 ± 0.08), nuggets (0.29 ± 0.09), and luncheon (0.12 ± 0.10), respectively (Fig. 1). In line with the findings of the present investigation, Pb was found in sausage sold in Iran at a concentration of 0.16 µg/g (Abedi *et al*., 2011). While the retailed meat products in Spain had a lower Pb concentration, at 0.007 µg/g (González-Weller *et al*., 2006). Pb levels were higher (14.84 and 16.69 µg/g) in chicken Frankfurter and hamburgers sold in Saudi Arabia (Korish and Attia, 2020). Similar to this, South Italian swine meat products (mortadella, baked ham, raw ham, cured sausage, salami, and würstel) were found to have higher Pb concentrations, ranging from 0.22 to 0.38 µg/g (Barone *et al*. 2021).

In the current investigation, Cd was detected in all examined samples. Panne had the highest Cd residual concentration (µg/g ww) among the examined chicken meat products (0.32 ± 0.06), followed by burger (0.27 ± 0.02), fillet (0.22 ± 0.05), nuggets (0.22 ± 0.01), and luncheon (0.17 ± 0.02) (Fig. 2). Comparatively, Iwegbue *et al*. (2008) reported values of Cd residual content ranged between 0.01 (chicken muscle) to 1.01 µg/g (chicken giblets) in the retailed chicken products in Nigeria,

In all tested chicken meat product samples, Zn was detected at levels ranging between 3.4 and 6.3 µg/g ww. The chicken burger had the highest Zn residual concentration, followed by fillet, luncheon, nuggets, and panne (Fig. 3). Relatively similar Zn level was recorded in Chilean rabbit meat and offal (9.5 ± 0.35) (Valenzuela *et al*., 2011). Furthermore, the hog meat products

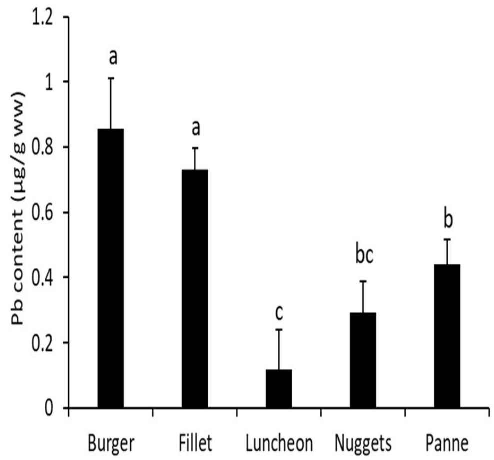

Fig. 1. Lead (Pb) residual contents (µg/ g ww) in chicken meat products retailed in Egypt. Data represent means ± SE (n = 20/ each product). Columns carrying different letter are statistically significant at p <0.05.

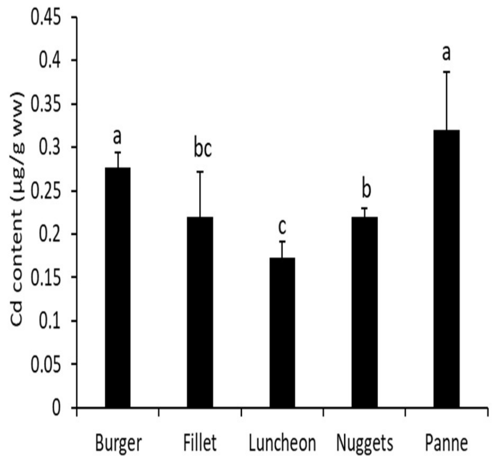

Fig. 2. Cadmium (Cd) residual contents (µg/ g ww) in chicken meat products retailed in Egypt. Data represent means ± SE (n = 20/ each product). Columns carrying different letter are statistically significant at p <0.05.

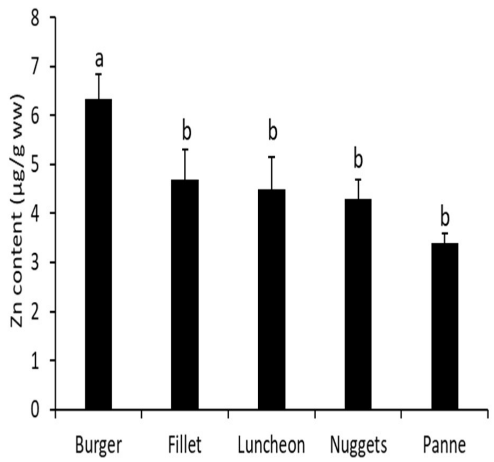

Fig. 3. Zinc (Zn) residual contents (µg/ g ww) in chicken meat products retailed in Egypt. Data represent means ± SE (n = 20/ each product). Columns carrying different letter are statistically significant at p <0.05.

sold in Italy had Zn residues of 5.71 to 7.32 ppm (Barone *et al.*, 2020). In Nigeria, retail chicken meat and giblets were found to have higher Zn concentrations (10.19-28.17 µg/g) (Iwegbue *et al.*, 2008).

All of the examined chicken meat product samples contained Cu at variable concentrations, with the levels varying from 0.23-3.01 µg/g ww. The chicken burger had the highest Cu level followed by luncheon, fillet, panne, and nuggets (Fig. 4). Similar Cu levels (0.80±0.01) were found in the rabbit meat and viscera in Chile (Valenzuela *et al.*, 2011). Besides, chicken meat and giblets retailed in Nigeria had Cu levels ranging between 0.4 to 1.6 µg/g (Iwegbue *et al.*, 2008). According to Barone *et al.* (2021), the hog meat products sold in Italy had higher Cu values ranging from 1.08 to 1.21 ppm. Higher levels (1.24-8.33) were recorded in beef meat products sold in Egypt (Elhelaly *et al.*, 2021).

Heavy metals are present in the environment naturally and enter an animal's body through contaminated feed and water. Heavy metals are characterized by their bioaccumulation, biomagnification, and stability to heat treatment except for Hg. The use of contaminated raw materials also contributes largely to the contamination of chicken meat products with heavy metals (Morshdy *et al.*, 2019; Thompson and Darwish 2019).

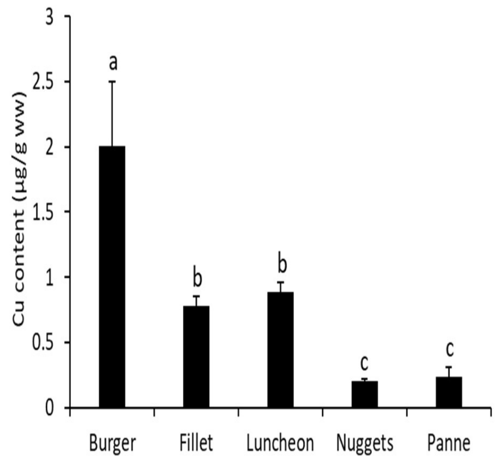

Fig. 4. Copper (Cu) residual contents (µg/ g ww) in chicken meat products retailed in Egypt. Data represent means ± SE (n = 20/ each product). Columns carrying different letter are statistically significant at p <0.05.

Dietary intakes and human health risk assessment

The analyzed chicken burger, fillet, luncheon, nuggets, and panne had residual Pb concentrations higher than the set maximum permitted limits (MPL) of Pb (0.1 g/g) (EC, 2006) in 100%, 100%, 50%, 80%, and 100%, respectively (Fig. 5). Excessive consumption of Pb-contaminated foods may have toxicological effects on the body, including cytotoxicity, mutagenicity, carcinogenicity, and disruptions of the central nervous system and hemoglobin synthesis (Darwish *et al.*, 2016; EFSA, 2010). However, the EDI of Pb in the analyzed samples was calculated, and the results showed that children's consumption of chicken burgers is the main cause of the highest exposure to Pb (EDI = 1.15 g/kg/day) (Table 1). The recommended provisional tolerable daily intake (PTDI) for Pb was determined by the World Health Organization at 3.5 µg/kg/day (WHO, 2010). The HR values for Pb exposure from the consumption of chicken meat products were calculated, and the results showed values far below one, indicating that consumption of such products has no potential hazards to human health. Likely, Darwish *et al.* (2015) concluded that eating cattle and sheep meat and offal in Egypt carries no risk of exposure to Pb.

Cadmium residue levels in the examined samples were high-

Table 1. Estimated daily intake and hazards risk associated with the occurrence of the tested heavy metals in chicken meat products retailed in Sharkia Governorate, Egypt

Product	Age	Pb		Cd		Cu		Zn		HI
		EDI	HR	EDI	HR	EDI	HR	EDI	HR	
Burger	Adults	0.49	0.12	0.16	0.16	1.16	NA	3.66	0.01	0.29
	Children	1.15	0.29	0.37	0.37	2.72	NA	8.55	0.03	0.69
Fillet	Adults	0.42	0.11	0.13	0.13	0.45	NA	2.71	0.01	0.24
	Children	0.98	0.25	0.29	0.29	1.05	NA	6.33	0.02	0.57
Luncheon	Adults	0.07	0.02	0.1	0.1	0.52	NA	2.59	0.01	0.13
	Children	0.16	0.04	0.23	0.23	1.2	NA	6.06	0.02	0.26
Nuggets	Adults	0.17	0.04	0.13	0.13	0.12	NA	2.49	0.01	0.18
	Children	0.39	0.09	0.29	0.29	0.28	NA	5.82	0.02	0.42
Panne	Adults	0.25	0.06	0.19	0.06	0.14	NA	1.97	0.01	0.13
	Children	0.59	0.15	0.43	0.15	0.32	NA	4.59	0.02	0.31

Pb: lead, Cd: cadmium, Cu: Copper, Zn: Zinc, EDI: Estimated daily intake, HR: Hazard ratio, HI: Hazard index

er than the established MPL (0.05 ppm) (EC 2006) in 50%, 100%, 60%, 70%, and 100% of the chicken burger, fillet, luncheon, nuggets, and panne, respectively (Fig. 5). Consumption of Cd-contaminated foods is linked to the development of nephropathy, renal failure, bone weakening, and carcinogenesis (Morshdy *et al*., 2013). The highest EDI of Cd was recorded for chicken panne (0.43 μg/kg/week) when consumed by children. The recorded EDI of Cd for all examined products was within the established PTDI for Cd (1 μg/kg/day) (WHO, 2010). Additionally, none of the analyzed samples' computed HR values for Cd exceeded one (Table 1), indicating that ingesting such chicken products would not be harmful to the public's health. Elhelaly *et al*. (2021) reported that Cd residues in the meat products in Egypt would not pose a risk to Egyptian consumers, which is consistent with the findings in the current study. Though unlikely, Darwish *et al*. (2015) suggested that ingestion of sheep and cattle offal in Egypt may increase the risk of Cd exposure.

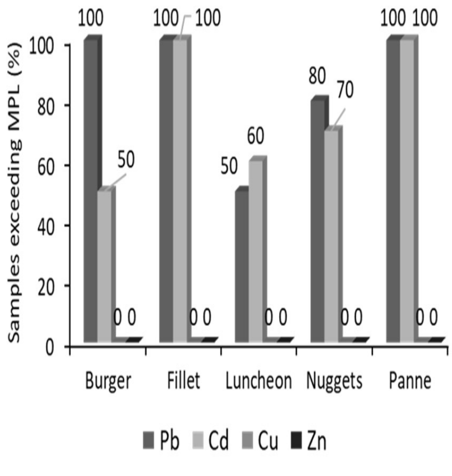

Fig. 5. Percentages of samples (%) exceeding maximum permissible limits of the examined metals.

All examined chicken meat product samples had residual Zn content within the established MPL (50 ppm) (EC, 2006). However, the EDI of Zn for all samples exceeded the recommended PTDI (1 μg/kg/day). Among the examined samples, a chicken burger would provide the highest Zn intake followed by fillet, luncheon, nuggets, and panne (Table 1). The calculated HR values for Zn were well below one, showing that consumption of such products would not be associated with any significant health hazards. Similar intake levels of Zn were noted in South Korea and Italy (Khan *et al*., 2014; Licata *et al*., 2004). Zn is a necessary trace element for the proper functions of the body's systems, but too much Zn can have negative side effects including vomiting, sleeplessness, and neurodegenerative illnesses (Faa *et al*., 2008).

Copper content did not exceed the established MPL (5 ppm) (EC, 2006) in all examined chicken meat product samples (Table 1). The recorded EDI of Cu exceeded the PTDI of Cu (0.5 μg/kg/day) (WHO, 2010), in the chicken burger, fillet, and luncheon, particularly among children. Since there is no information on the RfD values for copper, the HR of copper was not relevant to this investigation. Similar reports of high Cu intake came out of Poland (Sujka *et al*., 2019). Several enzymes in the body require copper to function normally, but too much copper can cause hyperthyroidism, allergic reactions, and hepatic cirrhosis (Darwish *et al*., 2014).

Calculating the HI for mixed pollutants throughout the investigated chicken meat products yielded values below one overall, showing that Egyptian customers would not be at risk of health problems from consuming such products.

CONCLUSION

According to the study's findings, Pb, Cd, Cu, and Zn were detected at variable concentrations in all the samples that were tested. Residual concentrations of the tested metals in several samples are over the suggested MPL. However, all the investigated samples' computed HR and HI for the tested metals did not go above the value of one, showing that consuming such chicken meat products would not pose human health risks.

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CONFLICT OF INTEREST

The authors declare that they don't have conflict of interest.

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