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Risks assessment of toxic metals in canned meat and chicken

Morshdy, A.E., Yousef, R.E., Tharwat, A.E. and *Hussein, M.A.

Food Control Department, Faculty of Veterinary Medicine, Zagazig University, Zagazig 44519, Egypt

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Abstract

Canned meat and chicken are common and popular protein sources around the world because they constitute low-cost and affordable products. However, canned meat and chicken might become sources of human exposure to chemical residues such as heavy metals. This study aimed to estimate the residual contents of six heavy metals, namely leads (Pb), cadmium (Cd), arsenic (As), mercury (Hg), aluminium (Al), and tin (Sn) in the samples of canned beef, corned beef, and chicken luncheon. Likewise, estimated daily intakes (EDI), potential health risks, hazard quotient (HQ), and hazard index (HI), of the heavy metals associated with the consumption of such products among the Egyptian population, were calculated. Comparing the obtained results with available maximum permissible limits (MPL) of Egyptian and international standards revealed that acceptability rate at 20%, 15%, and 35% in Pb; 40%, 25%, and 45% in Cd; 30%, 25%, and 35% in As; 25%, 20%, and 35% in Hg; 15%, 10%, and 15% in Al of the canned beef, corned beef, and chicken luncheon, respectively. Whereas all samples were accepted according to the MPL of Sn. The calculated HQ and HI for the examined heavy metals based on the daily intakes revealed values of canned beef and chicken luncheon <1.0 indicating the safety of consumer meanwhile, the value was 1.021 for canned corned beef indicating potential human health risks. Therefore, it is advisable to reduce the daily intake of canned corned beef.

1. Introduction

Canned meat and chicken are essential components of the human diet because they contain a significant amount of nutrients, including trace elements. Canned products have a long shelf life, do not require refrigeration, and do not require special handling during transportation or distribution. The term "canned food" refers to food that is packaged in metal cans, glass jars, or plastic containers and has a long shelf life due to the pasteurization process and the packaging's airtightness, which prevents air and contaminants from entering (Kowalska *et al*., 2020). Chemical preservatives, such as sodium nitrate or potassium nitrate, are also present in some canned foods (Amit *et al*., 2017). Chemical pollutants, the primary source of which is the environment, as well as faulty technological processing or packing, can be found in canned meat or chicken, regardless of their taste and nutritional value. Heavy metals from man-made pollution sources are continuously released into aquatic and terrestrial ecosystems, raising concerns about anthropogenic pollution's impact on ecosystems. Because of their toxicity, bioaccumulation, and biomagnifications in the food chain, heavy metal contamination is a severe threat (Demirezen and Uruc, 2006; Morshdy *et al*., 2013). Heavy metals, among other contaminants, pose a serious threat to human health (Ociepa-Kubicka and Ociepa, 2012). For instance, lead (Pb) damages and destroys erythrocytes, weakens the bones; reduces resistance; disturbs the metabolism of elements essential for human life, i.e., iron, copper, zinc, and selenium iodine, nervous system blocking; causes the loss of appetite; causes paralysis; causes colic and muscle cramps; raises blood pressure; damages the marrow; damages the kidneys; and liver (Sobhanardakani *et al.,* 2017). Cadmium (Cd) is a heavy metal with no known physiological function in the body. Cadmium is the main cause of *itai-itai* disease that is reported among Japanese people with heavy fish consumption. Such a disease is characterized by kidney dysfunction and osteomalacia (Nishijo *et al*., 2017). Besides, Cd is considered a group B1 carcinogen (IARC,

*Corresponding author.
Email: *elged2010@yahoo.com*

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2016). Arsenic (As) is another heavy metal introduced to the environment via arsenical compounds that are used as fungicides and admixtures to animal feed, veterinary medicines, corrosion inhibitors, tanning agents, and wood protection agents and were even used as the first choice in the treatment of syphilis (Szkoda, 2009). The supply of inorganic arsenic to humans leads to disturbance in the functioning of the kidneys and the liver, anaemia, disturbance in the alimentary tract, and a decrease in body mass may result in neoplastic processes (Reichard and Puga, 2010). Tin (Sn) was introduced to the meat or poultry meat due to internal surface corrosion of tinned cans and was associated with watery vomiting, diarrhoea, sickness, and great abdominal (Sedgwick, 1888). Mercury (Hg) is a toxic metal that commonly contaminates the environment due to its extensive use. This element accumulates in the kidneys, brain, and hair. Acute Hg toxicity results in lung impairment, while chronic toxicity is characterized by neurological and psychological disorders such as tremors, restlessness, changes in personality, depression, sleep disturbance, and irreversible kidney damage (Järup, 2003). Aluminium (Al) is the third most abundant metal in the Earth's crust widely spread throughout the environment, especially in the food chain. Also, is considered a non-essential metal causing urological symptoms (Glynn, 1999). The current study was designed for the evaluation of residual contents and risk assessment of six toxic metals including Pb, Cd, As, Hg, Al, and Sn in three canned meat and chicken products (canned beef, canned corned beef, and canned chicken luncheon) retailed in Egypt.

2. Materials and methods

2.1 Sample collection

A total of sixty canned meat and chicken samples of canned beef, canned corned beef, and canned chicken luncheon (twenty each) were collected randomly and equally from grocery stores and hypermarkets in Sharkia Governorate, Egypt. Samples were collected from April to October 2020. Samples were kept at room temperature in the laboratory of Meat Hygiene, Food Control Department, Faculty of Veterinary Medicine, Zagazig University, Egypt till the time of metal extraction and measurements.

2.2 Sample preparation

Sample preparation and metal measurements were done according to a previous method (Finerty *et al.,* 1990). In short, one gram of each canned sample was digested in 5 mL of a digestion solution containing 3 mL nitric acid 65%, and 2 perchloric acids 70%. The homogenate was kept at room temperature for 12 hrs. Then, the mixture was heated at 70°C for 3 hrs in the water bath with swirling every 30 mins. The digested mixture was allowed to cool to room temperature, and then diluted with 20 mL DDW, and filtered by using filter paper. The filtrate was kept at room temperature until heavy metal measurement.

2.3 Analytical procedures

The graphite furnace atomic absorption spectroscopy (Perkin Elmer® PinAAcle™ 900T atomic absorption spectrophotometer (Shelton, CT, USA) was used for the measurement of Pb, Cd, Al, and Sn. While As and Hg were measured using hydride generation/cold vapour atomic absorption spectroscopy (Shelton, CT, USA). All the analyses were done at the central laboratory, Faculty of Veterinary Medicine, Zagazig University, Egypt.

2.4 Quality assurance and quality control

The reference material DORM-3 Fish protein prepared by the National Research Council; Canada was used for quality assurance of the analytical procedures. The detection limits (µg/g) for the analysed metals were 0.01 for Pb, 0.005 for Cd, 0.02 for As, 0.01 for Hg, and 0.02 for Sn, 0.10 for Al. The detected levels for the tested metals were expressed as µg/g wet weight (µg/g WW).

2.5 Estimated daily intake

Estimated daily intake (EDI) values of the detected heavy metals via consumption of canned meat and chicken products by the Egyptian population were calculated based on the following equation according to US EPA, (2010):

$$\text{EDI } (\mu g/kg/day) = C_m * F_{IR}/BW$$

Where C_m is the concentration of the tested metal (µg/g WW); F_{IR} is the ingestion rate of meat by the Egyptian population. F_{IR} was set at 54.63 g/day for meat (OECD, 2021) and 47.67 g/day g/day for chicken (Helgi Library, 2018); BW is the bodyweight of Egyptian adults; this was set at 70 kg.

2.6 Health risk assessment

The non-carcinogenic risk, hazard quotient (HQ), of the tested heavy metals was calculated based on the following equation according to US EPA, (2010):

$$HQ = EDI/RFD*10^{-3}$$

Where RFD is the recommended reference dose (RfD) (mg/kg/d) 0.004, 0.001, 0.0003, 0.0005, 1, and 0.6 for Pb, Cd, As, Hg, Al, and Sn, respectively (US EPA, 2010).

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A hazard index (HI) was used to estimate the risk of mixed metals. HI was calculated from the following equation:

$$HI = \sum HRi$$

where *i* represents each metal

Values of HQ or HI of more than one indicate a potential risk to human health.

2.7 Statistical analysis

Statistical analysis was evaluated using one-way analysis of variance (ANOVA) followed by the post-hoc test, Tukey-Kramer HSD difference test (JMP) (SAS Institute, Cary, NC, USA). A $P<0.05$ was considered to be significant. Values were expressed as means±standard deviation (SD).

3. Results and discussion

3.1 Lead residues in examined canned meat and chicken

From the results obtained in Table 1, it is noticed that the level of Pb in examined canned beef, canned corned beef, and canned chicken luncheon samples detected in 100%, 100%, and 90% also, ranging from a 0.06 to 0.58, 0.08 to 0.61, and ND to 0.45mg/kg w/w with mean values 0.35±0.04, 0.39±0.04 and 0.21±0.02 mg/kg, respectively. Lead previously ranged from 0.224 to 0.334 mg/kg w/w in canned meat collected from Egypt (Khalafalla *et al*., 2016) and from 0.025 to 0.395 mg/kg in canned meat from Poland (Kowalska *et al*., 2020).

In this study, only 4 (20%), 3 (15%), and 7 (35%) of examined canned beef, canned corned beef, and canned chicken luncheon samples, respectively according to Egyptian standards (ES, 2010) and European Commission (EC, 2006) recommended that lead residues in meat and chicken must not exceed 0.1 mg/kg w/w lead in meat and meat products is caused by the release of Pb into the atmosphere by metal fumes or suspended particles from smelting or fuel combustion, as well as waste disposal, which contaminates animal feed and water and accumulates inside animal tissue (Ihedioha and Okoye, 2012). Aside from contaminated animal tissues, the air in the manufacturing environment, processing water, other raw materials, cooking utensils, and food packaging are all potential sources of Pb contamination in canned meat. Furthermore, the use of spices during processing and the release of significant amounts of Pb from the soldering line into the food are referred to as additional contaminants (Maggi *et al*., 1979).

3.2 Cadmium residues in examined canned meat and chicken

As recorded in Table 1, it is clear that the level of Cd in examined canned beef, canned corned beef, and canned chicken luncheon samples detected in 85%, 100%, and 80% also, ranged from ND to 0.10, 0.03 to 0.12, and ND to 0.11 mg/kg w/w with mean values 0.073±0.006, 0.081±0.007and 0.071±0.007 mg/kg w/w, respectively. The results of this study were in the same line with Khalafalla *et al*. (2016) who found Cd ranged from 0.039 to 0.057, mg/kg in canned meat collected from Egypt. Meanwhile, Kowalska *et al*. (2020) reported lower values for Cd ranging from 0.005 to 0.019 mg/kg w/w in canned meat from Poland. Comparing obtained results with the established maximum residue limit of 0.05 mg/kg of Egyptian standard (ES, 2010) and the European Commission (EC, 2006). The acceptability was 8 (40%), 5 (25%), and 9 (45%) of examined canned beef, canned corned beef, and canned chicken luncheon samples, respectively according to their residual content of Cd. Cadmium was introduced to meat products via spices because spices can contain Cd concentrations of up to 200 ng/g. As a result, Cd contamination of food products is a result of the manufacturing procedure, the equipment used during the process, as well as packaging materials and storage (Müller *et al*., 1996).

3.3 Arsenic residues in examined canned meat and chicken

The As residual level in examined canned beef, canned corned beef, and canned chicken luncheon samples detected in 65%, 85%, and 75% also, ranged from ND to 0.42, ND to 0.48, and ND to 0.44 mg/kg w/w with mean values 0.24±0.01, 0.28±0.02 and 0.27±0.02 mg/kg w/w, respectively (Table 1). Lower arsenic values obtained in canned meat from Poland ranged from 0.002 to 0.003 mg/kg (Kowalska *et al*., 2020).

According to Joint FAO/WHO Expert Committee on Food Additives (JECFA), the set MRL of As in food not exceeding 0.1 mg/kg w/w the acceptability was 6(30%), 5 (25%), and 9(45%) in canned beef, canned corned beef, and canned chicken luncheon samples (Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO), 2005). The high level of As in examined canned meat is attributed to distribution in the environment, especially underground water also, man-made formulas used in mining and agriculture (Othman *et al*., 2021).

3.4 Mercury residues in examined canned meat and chicken

Referring to the data in Table 1 Hg residues detected in 75%, 80%, and 65% also, ranged from ND to 0.09, ND to 0.11, and ND to 0.08 mg/kg with mean values 0.075±0.003, 0.086±0.003 and 0.068±0.003 mg/kg in

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Table 1. Residual content toxic metal mg/kg wet weight (PPM) in examined canned meat and chicken products (n = 20).

Product	Metal	Positive samples >DL	Minimum	Maximum	Mean ± SE (mg/kg w/w)	MRL (mg/kg w/w)	Acceptability%
Canned beef	Pb	20 (100%)	0.06	0.58	0.35±0.04[a]	0.1[1,2]	4 (20%)[1,2]
	Cd	17 (85%)	ND	0.10	0.073±0.006[ab]	0.05[1,2]	8 (40%)[1,2]
	As	13 (65%)	ND	0.42	0.24±0.01[a]	0.1[5]	6 (30%)[5]
	Hg	15 (75%)	ND	0.09	0.075±0.003[a]	0.01[3]	5 (25%)[3]
	Al	20 (100%)	0.13	8.21	3.92±0.53[a]	0.2[4]	3 (15%)[4]
	Sn	20 (100%)	0.9	11.62	4.55±0.53[a]	200[1,2]	20 (100%)[1,2]
Canned corned beef	Pb	20 (100%)	0.08	0.61	0.39±0.04[a]	0.1[1,2]	3 (15%)[1,2]
	Cd	20 (100%)	0.03	0.12	0.081±0.007[a]	0.05[1,2]	5 (25%)[1,2]
	As	17(85%)	ND	0.48	0.28±0.02[a]	0.1[5]	5 (25%)[5]
	Hg	16 (80%)	ND	0.11	0.086±0.003[a]	0.01[3]	4(20%)[3]
	Al	20 (100%)	0.15	7.95	4.02±0.49[a]	0.2[4]	2 (10%)[4]
	Sn	20 (100%)	1.18	12.36	5.05±0.62[a]	200[1,2]	20 (100%)[1,2]
Canned chicken luncheon	Pb	18 (90%)	ND	0.45	0.21±0.02[b]	0.1[1,2]	7 (35%)[1,2]
	Cd	16 (80%)	ND	0.11	0.071±0.007[b]	0.05[1,2]	9 (45%)[1,2]
	As	15 (75%)	ND	0.44	0.27±0.02[a]	0.1[5]	9 (45%)[5]
	Hg	13 (65%)	1.19	11.62	4.51±0.55[b]	0.01[3]	7 (35%)[3]
	Al	20 (100%)	2.5	12.36	5.05±0.62[a]	0.2[4]	4 (20%)[4]
	Sn	20 (100%)	1.14	10.50	4.59±0.49[a]	200[1,2]	20 (100%)[1,2]

Mean values with different superscripts are significantly different (p<0.05).
[1]Egyptian standard (2010), [2]European Commission (2006), [3]European Commission (2018), [4]European Commission (2016), [5]JECFA, FAO and WHO (2005)

canned beef, canned corned beef, and canned chicken luncheon samples, respectively. The obtained Hg values were lower than Khalafalla *et al*. (2016) who found Hg ranged from 0.332 to 0.450 mg/kg w/w in canned meat collected from Egypt. Meanwhile, lower values for Hg ranged from 0.00001 to 0.00004 mg/kg w/w in canned meat from Poland (Kowalska *et al*., 2020). The acceptability was 5 (25%), 4 (20%), and 7 (35%) of examined canned beef, canned corned beef, and canned chicken luncheon samples, respectively according to their residual content of Hg according to European Commission (EC, 2018). Mercury pollution is caused primarily by both natural and anthropogenic sources, as mercury has been used in a variety of industrial applications. All these sources result in mercury disposal in the environment (Bakir *et al*., 1976)

3.5 Aluminium residues in examined canned meat and chicken

Aluminium residues were detected in 100% of examined samples, ranging from 0.13 to 8.2, 0.15 to 7.95, and 0.13 to 8.29 mg/kg with mean values 3.92±0.53, 4.02±0.49and 3.54±0.54 mg/kg w/w in canned beef, canned corned beef, and canned chicken luncheon samples, respectively (Table 1). Comparable Al values from 2.29 to 7.69 mg/kg w/w were detected in 100% of canned tuna samples collected from Lebanon (Al Ghoul *et al*., 2020). The acceptability was 3 (15%) canned beef, 2 (10%) canned corned beef, and 4 (20%) canned chicken luncheon samples, respectively according to their residual content of Al according to the European Commission (EC, 2016). Aluminium in the food chain comes from natural sources including water, food additives, and contamination by aluminium utensils and containers (Greger, 1992).

3.6 Tin residues in examined canned meat and chicken

The recorded results in Table 1 declared that Sn residues detected in 100% of examined samples, ranged from 0.90 to 11.62, 1.18 to 12.36, and 1.14 to 10.50 mg/kg with mean values 4.55±0.53, 5.05±0.62, and4.59±0.49 mg/kg w/w in canned beef, canned corned beef, and canned chicken luncheon samples, respectively. Comparable values from 0.75 to 2.30 mg/kg were detected in 100% of canned meat samples collected from Egypt (Khalafalla *et al*., 2016). Meanwhile, lower values for Sn ranged from 0.005 to 0.0174 mg/kg w/w in canned meat from Poland (Kowalska *et al*., 2020). Concerning the established limit of Sn in canned meat (200 mg/kg w/w all examined samples were accepted according to ES (2010) and EC (2006). Tin usually migrates from the tin-coated can into the canned product producing a potential alteration in the flavour (Al Ghoul *et al*., 2020). There were no significant differences detected among As, Al, and Sn between the examined canned products (p>0.05), indicating that the source of these metals was evenly distributed between products. Meanwhile, Pb, Cd, and

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Hg in canned chicken luncheon were significantly lower ($p<0.05$) than canned beef and canned corned beef ($P<0.05$). The difference could be due to the longer life of cattle, which accumulates more metal than poultry, or to the free-range system in cattle breeding, which is more prone to metal contamination than poultry.

3.7 Population risk assessment due to consumption of canned meat and chicken product

This study was extended to estimate the potential health risks associated with the consumption of such meat and chicken products via calculation of EDI, HQ, and HI. The calculated EDI values (µg/kg/day) for Pb were 0.273, 0.311, and 0.148, for Cd, were 0.057, 0.063, and 0.049; for As were 0.195, 0.220, and 0.187; for Hg were 0.059, 0.067, and 0.047; for Al were 3.060, 3.144, and 2.574; for Sn were 3.52, 3.94 and 3.13 via ingestion of canned beef, canned corned beef, and, chicken luncheon, respectively (Table 2). Such values were within the provisional tolerable weekly intakes of the examined heavy metals as established by World Health Organization (WHO, 2010). Further calculation of HQ for the examined metals revealed values far below one for all examined metals indicating that canned meat and chicken would not pose health risks associated with these metals. Similar safe HQ values were reported for Al, and Sn in Lebanon (Al Ghoul *et al*., 2020). However, lower HQ values for Pb, Cd, As, Hg, and Sn in Poland (Kowalska *et al*., 2020). Besides, the calculation of HI for mixed contaminants revealed values lower than one for canned beef and canned chicken luncheon. However, a higher than one in the case of canned corned beef indicates that excessive consumption of canned corned beef might pose potential health risks for Egyptian consumers.

4. Conclusion

The obtained results in the present study revealed the detection of Pb, Cd, As, Hg, Al, and Sn in all examined samples at variable levels. Several samples had residual levels higher than the recommended MPL, particularly for Pb, Cd, As, and Hg. The calculated EDI, HQ, and HI revealed that excessive consumption of canned corned beef might pose health risks for the Egyptian population, and therefore, it is advisable to reduce the consumption of such canned products.

Conflict of interest

The authors declare no conflict of interest.

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Table 2. Dietary intakes and health risk assessment of heavy metals due to consumption of canned and chicken in Egypt.

Product	Pb		Cd		As		Hg		Al		Sn		HI
	EDI	HQ	EDI	HQ	EDI	HQ	EDI	HQ	EDI	HQ	EDI	HQ	
CB	0.273	0.068	0.057	0.057	0.195	0.648	0.059	0.118	3.060	0.0031	3.520	0.0058	0.900
CCB	0.311	0.078	0.063	0.063	0.220	0.735	0.067	0.135	3.144	0.0032	3.940	0.0065	1.021
CCL	0.148	0.037	0.049	0.049	0.187	0.622	0.047	0.093	2.574	0.0026	3.130	0.0052	0.809

CB: Canned beef, CCB: Canned corned beef, CCL: Canned chicken luncheon, EDI: Estimated daily intake (µg/kg/day), HQ: Hazard quotient, HI: Hazard index

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