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RESEARCH ARTICLE

Residues of lead, cadmium, mercury and tin in canned meat products from Egypt: an emphasis on permissible limits and sources of contamination

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Abstract In an attempt to determine the residual levels of lead (Pb), cadmium (Cd), mercury (Hg) and tin (Sn) in canned meat products marketed in Egypt, a total number of 160 random samples (40 each) of canned chicken luncheon (CCL), canned beef luncheon (CBL), canned frankfurter (CF) and canned corned beef (CCB) were randomly collected from different supermarkets in Egypt to be analyzed using atomic absorption spectrophotometry. From the obtained results, it was found that the mean values of residual levels of Pb in examined CCL, CBL, CF and CCB samples were 0.330, 0.224, 0.206 and 0.334 mg/kg, respectively, while those of Cd were 0.057, 0.053, 0.039 and 0.042 mg/kg, those of Hg were 0.387, 0.450, 0.402 and 0.332 mg/kg, and finally those of Sn were 2.061, 2.308, 0.755 and 1.997 mg/kg. The obtained results were compared with the permissible limits of heavy metals recommended by international and national authorities. In addition, the public health significance as well as the sources of contamination of canned meat products by heavy metals were addressed.

Keywords Heavy metal residues · Canned meat products · Lead · Cadmium · Mercury · Tin

1 Introduction

Meat and meat products constitute a large portion of human diet and represent an important source of animal protein and a wide range of other nutrients, but may also carry toxic substances. Canned food is widely distributed and a popular food source around the world, because they constitute inexpensive and affordable products (Storelli et al. 2010). In Egypt, there are several popular canned meat and meat products. However, the assessment of the safety of such products does not attract the attention of researchers, so there is only limited information about their status.

Lead (Pb), cadmium (Cd), mercury (Hg) and tin (Sn) are widely distributed heavy metals in our environment. It is known that these elements have no beneficial effects for human beings, and there is not any known homeostasis mechanism for them (Vieira et al. 2011). Whilst, they have several adverse effects on human health. Pb is a metabolic poison and a neurotoxin that binds to essential enzymes and several other cellular components and inactivates them (Cunningham and Saigo 1997). Moreover, it is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular diseases in adults (EC 2002). Cd is recognized as one of the most toxic elements to human beings and animals. It predominantly accumulates in kidney, bound to metalothioneines, with a biological half-life of more than 10 years. Excessive long-term Cd exposure may produce irreversible adverse renal effects as reported by WHO (1992). Cd toxicity affects tissues such as appetite and pain centers (in the brain), brain, heart

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and blood vessels, kidney and lungs. This toxicity may cause anemia, dry and scaly skin, emphysema, fatigue, hair loss, heart disease, depressed immune system response, hypertension, joint pain, kidney stones or damage, liver dysfunction or damage, loss of sense of smell, lung cancer, pain in the back and legs and yellow teeth in humans (Kocak et al. 2005). Acute Hg poisoning results in lung damage, while chronic exposure is characterized by neurological and psychological disorders such as tremors, changes in personality, restlessness, anxiety, sleep disturbance and depression, and irreversible kidney damage even after exposure cessation (Järup 2003).

Acute toxicity resulted from dissolution of Sn from the internal surfaces of tinned cans and associated with watery diarrhea, vomiting, sickness and a great abdominal pain was recorded by Barker and Runte (1972) and Sedgwick (1888).

Although some people are exposed to these heavy metals at their workplace, for most people the main source of exposure to these toxic substances is through ingestion of food and drinking of water. Although the resulting public health risks of any contaminant are a function of concentration, it is well-known that long duration of intake of these metals at relatively low levels can lead to adverse results (Castro-González and Méndez-Armenta 2008). Hence, the accumulation of heavy metals in our environment is of increasing concern nowadays due to food safety issues and potential public health hazards (McLaughlin et al. 1999). The discharge of hazardous pollutants into the environment obstinately raises heavy metal concentrations that enter the food chain. Contamination of meat and meat products with heavy metals can take place during the handling, transportation and processing of meats, from farm to fork. Contact between food and metal, including but not restricted to processing equipment and utensils, food store, food packages and food cans, is another important source of food contamination with heavy metals (Morgan 1999). In this concern, it was found that the addition of spices to canned food and soldering process of cans add considerable amount of heavy metals to canned food (Maggi et al. 1979; Müller et al. 1996; Mol 2011).

The monitoring of meat and meat products for chemical hazards is required to ensure that approved compounds are not being misused and do not contain a risk to consumers (Pullen 1990). Thus, several monitoring programs have been carried out in several nations with the purpose of avoiding the distribution of foodstuffs that contain chemical residues in high levels and could have a risk to human health if consumed (López-Alonso et al. 2000). On contrary, in Egypt there is not any official monitoring programs by the national authorities determines the level of heavy metals in foods (Hassan et al. 2015). Therefore, the present study was designed to determine the residual concentrations of some heavy metals (Pb, Cd, Hg and Sn) in canned chicken luncheon (CCL), canned beef luncheon (CBL), canned frankfurter (CF), and canned corned beef (CCB) marketed in Egypt.

2 Materials and methods

2.1 Collection of samples

A total number of 160 random samples of canned meat, 40 samples of CCL, CBL, CF, and CCB each were collected from different markets in Beni-Suef, Assiut and Cairo governorates, Egypt. The collected samples were transferred immediately and in their original cans to the laboratory for further preparation and identification.

2.2 Digestion of samples

Meat product samples were dried at 105 °C, and then subjected to dry ashing at 450 °C/5 h in a muffle furnace, using high purity magnesium oxide and magnesium nitrate as ashing aids to limit volatilization losses of some elements. For each metal two gram of dried samples were dissolved in distilled water in a digestion flask and digested with a mixture of 10 ml of nitric acid (HNO_3) 65 % (suprapure, Merk, Darmstadt, Germany) and 2 ml of perchloric acid ($HClO_4$) 70 % (extra-pure-Merk, Darmstadt, Germany) (Zantopoulos et al. 1996). The content of the flasks was vigorously shaken and allowed to stand overnight at room temperature. Then, these flasks were heated for 3 h in water bath adjusted at 70 °C to ensure complete digestion of samples. During the heating period, the digestion flasks were vigorously shaken at 30 min intervals. Finally, the flasks were cooled to room temperature and each tube then was diluted with 20 ml de-ionized water, and filtered by using Watt man filter paper No. 42. The filtrate was collected in glass tubes and these tubes were capped with polyethylene films and kept at room temperature until analysis of residual concentrations of Pb, Cd, Hg and Sn (Tsoumbaris 1990).

2.3 Preparation of blank and standard solution

Blank and standard solutions using pure certified metal standards for Pb, Cd, Hg and Sn were prepared by the method described above (Sect. 2.2).

2.4 Instrument and measurement

Buck scientific 210VGP Atomic Absorption Spectrophotometer (AAS) was used to determine heavy metal levels in the selected samples. The digest, blank and standard solutions were aspirated by AAS and analyzed for heavy metal content. Analysis of Pb, Cd and Sn was conducted by air/acetylene flow (5.5/1.11/m) flame technique, while cold vapor technique was used for Hg determination (AOAC 1990). The analytical detection limits of Pb, Cd, Hg and Sn for the used instrumentation were 0.005, 0.02, 0.005 and 0.02 ppm, respectively.

2.5 Calculation

Pb, Cd, Hg and Sn concentrations were recorded directly from the digital scale of AAS and calculated according to the following equation:

$$\text{Heavy metal (ppm)} = \mathrm{R} \times \mathrm{D}/\mathrm{W}$$

where R is the reading of element concentration (ppm) from digital scale of AAS, D is the dilution of the prepared sample, and W is the weight of the sample.

The concentration or the absorption values of heavy metals in blank samples were also calculated and subtracted from each analyzed sample. The estimated values of Pb, Cd, Hg and Sn were expressed as mg/kg wet weight (ppm).

2.6 Statistical analysis

All the data were analyzed using SPSS/PCT (Foster 2001). Independent *T* test was performed to evaluate differences.

2.7 Comparing with permissible limits

The obtained results of residual concentrations of studied heavy metals in different canned meat products were compared with the acceptable limits recommended by national and international organizations, which are illustrated in Table 1.

3 Results and discussion

3.1 Residual levels of Pb in examined canned meat products

From the results recorded in Table 2, it is obvious that the residual level of Pb in examined CCL samples ranged from a non-detectable level (ND) to 1.140 mg/kg with a mean value of 0.330 mg/kg, while in CBL, it ranged from ND to 0.630 mg/kg with a mean value of 0.224 mg/kg (Table 2). The obtained results of Pb in CF (Table 4) ranged from ND to 0.630 mg/kg, with a mean value of 0.206 mg/kg. Concerning CCB (Table 5), residual levels of Pb ranged from ND to 0.830 mg/kg with a mean value of 0.334 mg/kg. There was no significant difference between the mean residual levels of Pb in all examined canned meat products ($p < 0.05$). The data outlined in Table 6 show that 27, 22, 29 and 33 out of 40 samples of each CCL, CBL, CF and CCB (representing 67.5, 55, 72.5 and 82.5 %, respectively), exceeded the maximum acceptable limit (0.1 mg/kg) of Pb in meat and meat products of bovine animals and poultry recommended by European Commission (EC 2006) and Egyptian Standards (ES 2010). With regard to the permissible limits of Pb (0.5 mg/kg) stated by Food and Agricultural Organization (FAO 1983) and Food and Drug Administration (FDA 2013), we found that 12, 9, 1 and 10 out of 40 samples of each CCL, CBL, CF and CCB (representing 30, 22.5, 2.5 and 25 %, respectively), were above such limits (Table 6).

Higher values of Pb reported in examined canned meat products can be explained in light of the concept of Ihedioha and Okoye (2012) who suggested that the presence of Pb in foods, including meat and meat products, is attributed to the release of Pb into the atmosphere by metal fumes or suspended particles from smelting or fuel combustion and disposal of wastes, which then contaminate animal feed and water and accumulates inside their tissues. Beside contaminated animal tissues, air in the manufacturing atmosphere, water used for processing, other raw materials, cooking utensils and food packages are potential sources of contamination of processed foods by Pb. In addition, the use of spices during processing (Landis and Ming-Ho 2004) and the release of substantial quantities of Pb from the soldering line into the food (Maggi et al. 1979) are referred to as additional sources.

Table 1 The maximum acceptable residual level of each heavy metal in meat and meat products of bovine animals and poultry, as recommended by national and international organizations (mg/kg wet weight of foodstuff)

Organization	Pb	Cd	Hg	Sn
EC (2006) and ES (2010)	0.10	0.05	–	200
FAO (1983) and FDA (2013)	0.50	–	–	–
JECFA (2000)	–	0.50	–	–
JECFA (2006)	–	–	–	250

Table 2 Residual levels of examined heavy metals in canned chicken luncheon samples (mg/kg) (n = 40)

Metal	Positive samples (>LOD)		Minimum	Maximum	Mean	Standard error
	No.	%				
Pb	33	82.5	ND	1.140	0.330	0.046
Cd	39	97.5	ND	0.110	0.057	0.004
Hg	37	92.5	ND	0.840	0.387	0.036
Sn	31	77.5	ND	6.220	2.061	0.281

LOD limit of detection, *ND* non-detectable: below limit of detection

Table 3 Residual levels of examined heavy metals in canned beef luncheon samples (mg/kg) (n = 40)

Metal	Positive samples (>LOD)		Minimum	Maximum	Mean	Standard error
	No	%				
Pb	31	77.5	ND	0.630	0.244	0.036
Cd	39	97.5	ND	0.100	0.053	0.003
Hg	39	97.5	ND	0.900	0.450	0.039
Sn	37	92.5	ND	6.350	2.308	0.260

LOD limit of detection, *ND* non-detectable: below limit of detection

3.2 Residual levels of Cd in examined canned meat products

The results illustrated in Table 2 reveal that the Cd residual levels in the examined CCL samples ranged from ND to 0.110 mg/kg with a mean value of 0.057 mg/kg, and Table 3 denotes that in CBL levels ranged from ND to 0.100 mg/kg with a mean value of 0.053 mg/kg. Concerning CF, levels (Table 4) ranged from ND to 0.090 with a mean value of 0.039 mg/kg. Moreover, Table 5 shows that in CCB levels ranged from ND to 0.110 with a mean value of 0.042 mg/kg. Compared with the maximum acceptable limit of Cd (0.05 ppm) in meat and meat products of bovine animals and poultry recommended by EC (2006) and ES (2010; Table 6), it was noticed that 23, 17, 12 and 12 out of 40 samples of each CCL, CBL, CF and CCB (representing 57.5, 42.5, 30 and 30 %, respectively), exceeded these limits. Nevertheless, in none of the examined samples the permissible limit of Cd (0.5 ppm) stated by JECFA (2006) was exceeded.

The residual concentrations of Cd reported in the current study that are higher than the permissible limits recommended by EC (2006) and ES (2010) might be explained in the light of previously published reports. Abdel-Sabour (2001) and Hassan et al. (2015) find that high levels of Cd in the Egyptian environment and accordingly in plants and animal tissues and products could be attributed to the increasing emission of Cd into atmosphere from mining and smelting industries and the contamination of river Nile with the industrial wastes especially by plastics industries. Besides, Cd escapes into the air from iron and steel production industries and the high usage of phosphate fertilizers. These findings support the concepts of Müller et al. (1996) and Bakircioglu et al. (2011) who declared that the addition of spices during production of canned meat might be the main reason for contamination with Cd, since spices could contain Cd concentrations up to 200 ng/g, so that contamination of food products by Cd is the result of the manufacturing procedure, the

Table 4 Residual levels of examined heavy metals in canned frankfurter samples (mg/kg) (n = 40)

Metal	Positive samples (>LOD)		Minimum	Maximum	Mean	Standard error
	No	%				
Pb	33	82.5	ND	0.630	0.206	0.026
Cd	36	90	ND	0.090	0.039	0.003
Hg	38	95	ND	0. 980	0.402	0.042
Sn	29	72.5	ND	5.280	0.755	0.178

LOD limit of detection, *ND* non-detectable: below limit of detection

Table 5 Residual levels of examined heavy metals in canned corned beef samples (mg/kg) (n = 40)

Metal	Positive samples (>LOD)		Minimum	Maximum	Mean	Standard error
	No.	%				
Pb	36	90	ND	0.830	0.334	0.038
Cd	34	85	ND	0.110	0.042	0.004
Hg	28	70	ND	1.220	0.332	0.060
Sn	36	90	ND	5.460	1.997	0.238

LOD limit of detection, *ND* non-detectable: below limit of detection

Table 6 The percentage of samples exceeding the permissible limits of heavy metal residues recommended by national and international organizations (%) (n = 40)

Organization	Pb				Cd				Sn			
	CCL	CBL	CF	CCB	CCL	CBL	CF	CCB	CCL	CBL	CF	CCB
EC (2006) and ES (2010)	67.5	55	72.5	82.5	57.5	42.5	30	30	0	0	0	0
FAO (1983) and FDA (2013)	30	22.5	2.5	25	–	–	–	–	–	–	–	–
JECFA (2000)	–	–	–	–	0	0	0	0	–	–	–	–
JECFA (2006)	–	–	–	–	–	–	–	–	0	0	0	0

CCL canned chicken luncheon, *CBL* canned beef luncheon, *CF* canned frankfurter, *CCB* canned corned beef

equipment used during the process as well as packaging materials and storage. In this regard, the Ministry of Health ESR (1995) indicated that approximately 1/3 of cadmium dietary intake is attributed to the ingestion of animal products, while plant products provide the remaining 2/3.

3.3 Residual levels of Hg in examined canned meat products

The obtained results (Table 2) indicated that the residual levels of Hg in examined CCL samples ranged from ND to 0.840 with a mean value of 0.387 mg/kg. Referring to the data of CBL samples (Table 3), it ranged from (ND) to 0.900 with a mean value of 0.450 mg/kg. Whereas in examined CF samples it ranged from ND to 0.980 with a mean value of 0.402 mg/kg (Table 4). As illustrated in Table 5, the residual in CCB samples ranged from ND to 1.220 with a mean value of 0.332 mg/kg. The recorded residual levels of Hg in examined canned meat products are relatively low, and can be explained in light of published papers by the Ministry of Health ESR (1995) and Dudka and Miller (1999). Stating that consumption of seafood is the main source of the Hg accumulation in human bodies, and dietary intake of Hg through other food remains relatively low. They explain that fish and shellfish have a high ability to bio-accumulate environmental Hg in their tissues, therefore keep it in high levels, and have a distinct capacity to convert inorganic Hg into organic, thus, rendering Hg more easily transferable throughout the aquatic food chain. Therefore, there are not any recommended standards for Hg in other foods than seafood. In this concern it was reported that the main sources of food contamination with Hg may be industrial wastes, pesticides and fungicides (Zarski et al. 1997), while, Rashad et al. (2013) noticed reduced levels of Hg in the Egyptian environment in their study on environmental monitoring of Hg in soil, air and plants.

3.4 Residual levels of Sn in examined canned meat products

From Table 2 it can be recognized that the residual level of Sn in examined CCL samples ranged from ND to 6.220 with a mean value of 2.061 mg/kg, and in examined CBL samples it ranged from ND to 6.350 with a mean value of 2.30 mg/kg (Table 3), whereas it ranged from ND to 5.280 with a mean value of 0.755 mg/kg in examined CF samples (Table 4). Regarding CCB samples, it can be concluded from the data shown in Table 5 that it ranged from ND to 5.460 with a mean value of 1.997 mg/kg. Concerning the permissible limits of Sn in canned foods (Table 6), it was observed that none of the examined samples of canned meat products exceeded either the permissible limit of Sn stated by JECFA (2006) or of EC (2006) (250 and 200 mg/kg wet weight of canned food, respectively).

In general, the residual concentrations of Sn in all examined canned food items were quite low, which could be a result of improved quality assurance measures during processing and storage conditions of canned foods (EC 2001).

4 Conclusion

It could be concluded from the current study that the elevated values of Pb and Cd could be attributed to the contaminated animal tissues used for processing, air in the manufacturing atmosphere, water used for processing, other raw materials, cooking utensils and food packages as well as the use of spices during processing. Additionally, high Cd values support the previous reports of high Cd levels in the Egyptian environment. The reduced residual concentration of Hg in examined canned food samples reflects the low level of Hg in the Egyptian environment and supports the previously recorded concept that dietary intake of Hg through food remains relatively low and strictly linked to seafood. Sn residual levels in examined canned foods were relatively low, which could be a result of increasing improvements in quality assurance measures and storage conditions of canned food.

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