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# Heavy Metals and Trace Elements Composition in Certain Meat and Meat Products Sold in Egyptian Markets

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**Abstract**

Meat is a very complex system contains various materials to meet the needs of the human being. For most people, diet is the main route of exposure of heavy metals and trace elements, and therefore the risk assessment of these elements to humans through dietary intake is important. In this investigation, 16 heavy metals and trace elements concentration (As, Cd, Pb, Al, Cu, Zn, Se, Mn, Fe, Ag, Sr, Cs, Cr, V, Ni and Ba) were evaluated (ppm) in 40 beef meat and sausage samples that have been collected from different stores in Egypt using the Inductively Coupled Plasma Optical spectroscopy (ICPOS) and the obtained results were compared with the permissible limits. The results revealed that there is a wide variation in the contents of the heavy metals and trace elements (ppm) of the examined samples. Sausage was found to contain the highest concentrations of the previously mentioned elements.

***Keywords:*** Heavy metals; trace elements; Inductively Coupled Plasma Optical spectroscopy; meat.

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## 1. Introduction

Meat as the flesh of animals used for food is a relevant dietary source of proteins, essential amino acids, chemical elements (e.g. iron, zinc) and vitamins (e.g. B12, D). Yet, the healthy image of meat is tarnished by its negative association with non-nutritional issues like the presence of various toxic contaminants. Taking consumer behavior into consideration, there was primarily the demand for sufficient food, afterwards the desire for more and more quality in the food area and nowadays everybody asks for safe and healthy food with high quality. With increasing global distribution of feed, food and ingredients the different countries in our world have never been before more dependent on each other with respect to their food supply [1]. A united approach with consistent standards based on sound science and robust controls is necessary to ensure consumers' health and to maintain consumers' confidence. Chemical composition of meat depends on kinds and degrees of animal feeding. The demand for mineral compounds depends on age, physiological state, and feed intake as well as on living conditions. In order to promote animal growth and prevent diseases, all kinds of metals are added into animal feed excessively [2].

Food consumption had been identified as the major pathway of human exposure to heavy metals, and consuming foodstuff threatens the health of the population. The increasing demand of food safety has accelerated research regarding the risk associated with food consumption contaminated by heavy metals [3]. Moreover, the use of large quantities of agrochemicals such as metal-based pesticides and fertilizers plays an important role in the contamination of foodstuffs by heavy metals [4]. Excess amounts of heavy metals from anthropogenic sources that enter into the ecosystem may lead to geo-accumulation and bioaccumulation, which in turn pollute the environment and also affect the food chain and ultimately pose serious human health risks [5]. Therefore, the Food and Agricultural Organization (FAO), World Health Organization (WHO), US Environmental Protection Agency (USEPA), and other regulatory bodies of various countries have established the maximum permitted concentrations of heavy metals in foodstuffs [6]. It must be noted that although metals can change their chemical form, they cannot be degraded or destroyed. In the work of Upreti et al. [7] it was suggested that the gut micro flora have a marked capacity to cope with the increased load of ingested metals and may contribute significantly in the protection against metal toxicity suggesting that the protection can be easily lost with any compromise to the gut epithelium.

Considering that meat, is an important source of toxic metal exposure to humans, but also a valuable source of some essential elements (mainly Cu, Fe, Zn and Se; Loópez-Alonso et al., [8]) it is important to explore heavy metal and trace element (As, Cd, Pb, Al, Cu, Zn, Mn, Cr, Fe, Se, Cs, Ag, Ni, Sr, V and Ba) concentrations in beef meat and sausage consumed in Egyptian market in the first quarter of 2014. Moreover, the data were compared with the permissible limits and estimates of dietary exposures.

## 2. Materials and methods

### *2.1. Sampling*

A total of 40 samples were collected from different shops in Cairo and Giza during the first quarter of 2014. The samples were classified into 2 groups: (a) beef meat and (b) sausage. The collected samples were analyzed independently with three replicates per sample. All collected samples were put in clean polythene bags and brought to the laboratory on the same day for preparation and treatment.

### *2.2. Preparation and treatment of samples*

The collected samples were washed with distilled water to remove any contaminated particles. Then samples were chopped into small pieces using clean ceramic knife and then dried in an oven at 90°C until a constant weight was obtained. The dried samples were crushed in a ceramic mortar into fine powder, sieved and then stored in polyethylene bags in desiccators in the dark until used for acid digestion.

### *2.3. Acid digestion of samples*

Milestone microwave system was used for digestion of powdered samples. Samples (0.2 g) were weighed and digested with 10 ml of conc HNO3 (65%) and 5 ml $H_2O_2$ in a microwave digestion system (digestion conditions are; first step with power: 650 W for 10 min, second step with power: 350 W for 10 min) and then diluted by double distilled de-ionized system 18 mega Ω cm. Determinations of the elements in all samples were carried out using a Prodigy Axial high dispersion ICPOS (RF frequency: 40, RF power: 1.3 K watt, Coolant gas flow rate: 18 L/min, Auxiliary flow rate: 0.3 L/min, Carrier gas pressure: 34 psi, Integration time: 4 sec, Sample intake rate: 1.0 ml/sec) in the Central Lab for elemental and isotopic analysis in Nuclear Research Center, Egyptian Atomic Energy Authority.

### *2.4. Analysis of heavy metals*

Standard stock solutions of 1000 ppm for all studied elements were obtained for calibration. All samples were collected and analyzed in triplicate and statistical analysis was performed by prism to calculate means ± standard errors (SE).

## 3. Results and discussion

Results of Heavy metals and trace elements (As, Cd, Pb, Al, Cu, Zn, Mn, Fe, Cr, Se, Cs, Ag, Ni, Sr, V and Ba) concentrations (ppm) in beef meat and sausage are represented in Table 1. The concentrations of heavy metals and trace elements in studied samples varied greatly between products and between samples.

### *3.1. As, Cd and Pb*

As, is an environmental toxicant, detected in all examined meat samples in the range of 0.326 to 2.6 ppm with mean 0.95± 0.15 ppm. In sausage samples, it was detected in only 4 samples with mean 0.199± 0.09 ppm. Our As results were considered high compared to those reported by Westöö and Rydälv [9] that As level in food, with the exception of some seafood, are generally well below 1 mg/kg wet weight except for some samples. One of the major mechanisms by which it exerts its toxic effect is through an impairment of cellular respiration by inhibition of various mitochondrial enzymes, and the uncoupling of oxidative phosphorylation [10].

Cd, is a non-essential toxic metal has no biological role, found as an environmental contaminant, both through natural occurrence and from industrial and agricultural sources. Human toxicity occurs through food chain magnification. Foodstuffs are the main source of Cd exposure for the non-smoking general population [11]. In the present study, although Cd was detected in all examined meat samples (0.179 to 4.156 ppm with mean 1.105± 0.26), but it was found in only 2 (10%) sausage samples (1.098 and 1.171 ppm with mean 0.114± 0.08). Our mean Cd level was higher than that reported by Mohamed and Nosier [12] in chicken shawerma (Egypt), Iwegbue et al. [13] in chicken meat (Nigeria) and Alturiqi and Albedair [14] in meat and meat products (Saudi Kingdom). At the same time our detected Cd level was slightly lower (1.68± 1.76) than that detected by Gonzalez-Weller et al. [15] in chicken meat in spain markets. According to the FAO limits (0.1mg/kg) and EC regulations (0.05 mg/kg wet weight for bovine meat) [16, 17], the obtained Cd values of all meat and 10% of sausage samples are above these limits. In the food category "meat and meat products, and offal" there are 3.6% of bovine, sheep and goat meat samples exceed the maximum levels (MLs) [18].

Cd concentrations in meat samples had an increasing trend with age. There is a significant positive linear relation between animal age and renal or hepatic Cd levels [19]. Cd absorption after dietary exposure in humans is relatively low (3–5%), but Cd is efficiently retained in the kidney and liver in the human body, with a very long biological half-life ranging from 10 to 30 years. Cd can also cause bone demineralization, either through direct bone damage or indirectly as a result of renal dysfunction. Cd bioavailability, retention, and consequently toxicity are affected by several factors such as nutritional status (low body iron stores) and multiple pregnancies, preexisting health conditions or diseases. The International Agency for Research on Cancer has classified Cd as a human carcinogen (Group 1) on the basis of occupational studies [18]. Cd was also listed as endocrine-disturbing substance and may lead to the development of prostate and breast cancer [20].

Pb, in meat is a toxic metal of primary concern, present at low concentrations in most foods. Contaminations of food during processing or food production in contaminated areas are the main reasons for enhanced Pb intake via foodstuffs. In the present study Pb concentration of was found in all examined meat samples with mean1.809± 0.16 ppm (ranging from 0.45 to 2.81 ppm) and in only 2 sausage samples (1.892 and 1.756 ppm). According to FAO/WHO [21] and EC Commission Regulation [22] which established limits for Pb content of 0.3 mg/kg (fresh weight basis), i.e., 1.44 mg/kg dry weight (considering 79 % moisture content) in food, 20% of examined samples in this study were below the permissible limit, 10% were exactly as MLs and 70% exceeded the MLs. The mean value of Pb in the present study was corresponding with that reported by Mohamed and Nosier [12] in chicken shawerma (1.48 ±1.771 ppm) but was more than Gonzalez-Weller et al. [15] in chicken in Spain (6.94± 4.63µg/ kg) and Alturiqi and Albedair [14] in sausage in Saudi Kingdom (15.43±1.22 µg/g dry weight, mean ± SD). Pb is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults. The high level of Pb may be attributed to the wide spread of environmental contamination [23], air borne traces, water pollution and contaminated fumes and effluents emitted from traffic [24].

**Table (1):** Heavy metals and trace elements (mean ± SE) concentrations (ppm, dry weight) in meat (n=20) and sausage (n=20) samples.

| Metal | Meat | | | Sausage | | |
|---|---|---|---|---|---|---|
| | Min. | Max. | Mean | Min. | Max. | Mean |
| As | 0.326 | 2.6 | 0.95± 0.15 | ND | 1.37 | 0.2± 0.09 |
| Cd | 0.179 | 4.16 | 1.11± 0.26 | ND | 1.17 | 0.11± 0.8 |
| Pb | 0.45 | 2.81 | 1.81± 0.15 | ND | 1.89 | 0.18± 0.13 |
| Al | 21.79 | 265.6 | 96.62± 16.06 | 20.05 | 3305 | 460.4± 210.2 |
| Cu | 0.68 | 5.41 | 3.18± 0.3 | 1.44 | 6.92 | 3.45± 0.38 |
| Zn | 67.9 | 222.3 | 137.4± 11.48 | 19.83 | 65.21 | 38.59± 2.96 |
| Mn | 0.8 | 3.27 | 1.95± 0.17 | 3.32 | 18.38 | 8.4± 0.97 |
| Se | 0.79 | 2.14 | 1.42± 0.1 | ND | 1.42 | 0.13± 0.09 |
| Cr | 0.37 | 2.04 | 1.3± 0.11 | 0.33 | 3.44 | 1.13± 0.18 |
| Ni | 0.54 | 7.45 | 2.25± 0.45 | 1.09 | 3.71 | 2.22± 0.16 |
| Cs | 0.78 | 2.24 | 1.6± 0.11 | ND | 1.142 | 0.1± 0.07 |
| Fe | 82.95 | 352.9 | 190.5± 19.43 | 82.9 | 270 | 135± 10.48 |
| Ag | ND | ND | ND | ND | 1.11 | 0.11± 0.07 |
| Sr | 0.66 | 13.79 | 2.47± 0.84 | 3.99 | 27.9 | 11.15± 1.52 |
| V | 0.24 | 0.82 | 0.47± 0.04 | ND | 2.28 | 0.6± 0.17 |
| Ba | 0.49 | 14.7 | 3.06 ± 0.83 | 2080 | 9133 | 5007± 526 |

ND: Not detected (< detection limit, 1ppm).

### *3.2. Al, Cu, Zn, Mn*

Al, is widespread throughout nature, air, water, plants, and consequently in all the food chain [25]. Al was detected in all examined samples in the present study but with varying degree. The concentrations of Al in meat and sausage samples were ranging from 21.79 to 265.6 ppm with mean 96.62± 16.06 ppm and from 20.05 to 3305 ppm with mean 460.4± 210.2, respectively. It was clear from the results that Al level in meat samples was lower than that reported by Mohamed and Nosier [12] in chicken while in sausage samples Al level was higher. The results confirm that the Al content of foodstuffs may differ from sample to sample even in cases of the same product. Elevated Al content in meat samples may be due to the high Al content in plants that are eaten by the animals due to the high soil content of this element. However, several authors reported that the soil Al content is an important factor contributing to total Al concentration in plant tissues; samples taken from plants growing on high Al soils contained higher Al concentrations than similar plants growing on low-Al soils [25, 26]. At the same time, the high Al content in examined sausage samples was mainly due to food additives and processing in Al utensils [27]. Although there are several potential routes of exposure to this element, the diet is the main source of Al in the healthy population. Aluminum from the environment is present naturally in foods and beverages, but the content of this element increases mainly with processing, packaging, food additives, and cooking (utensils). In general, the Al content of frequently consumed food increased in the following order: beverages> food of animal origin> food of plant origin [28].

Cu and Zn are the cofactors to many enzymes and a key role of Cu in human health is also due to its involvement in absorption, utilization and transport of Fe in body, and so, prevention from the Fe deficiency [29]. The concentration of Cu and Zn (ppm) in the examined meat and sausage samples (Table 1) ranged from 0.68 to 5.41with mean 3.18± 0.3 and from 1.44 to 6.92 with mean 3.45± 0.38 (Cu), respectively; While Zn concentration (ppm) ranged from 67.9 to 222.3 with mean 137.4± 11.48 and from 19.83 to 65.21 with mean 38.59± 2.96, respectively. These values were higher than those reported in Saudi Kingdom by Alturiqi and Albedair [14] in meat and meat products. However, although our Cu concentration in the meat samples is lower than that reported in red deer muscle (11 mg/ kg dry weight) by Jarzyńska and Falandysz [29] but the Zn concentration was corresponding to their results (150 mg/ kg dry weight). Although, Cu and Zn are essential for good health but very high intakes can cause health problems [30]. The recommended intake of Cu for healthy adult is between 900 and 1300 µg/ day [31], and for Zn is between 3300 and 3800 µg/ day [32]. The adequate intake of these trace elements by Kabata-Pendias and Pendias [33] is 1.5–4 mg/ day (Cu) and around 10 mg/ day (Zn).

Mn, which in animal cells is associated as an enzymatic cofactor in mitochondria, takes a role in the regulation of cell metabolism, receptor binding and signal transduction pathways, and an estimated safe and adequate daily dietary intake of Mn for adolescents and adults ranges from 2 to 5 mg [34]. The UK Expert Group on Vitamins and Minerals assumed, for guidance purposes, that daily total Mn intakes up to 200 µg/ kg bw (14 mg for 70 kg bw man) in the general population is unlikely to result in adverse effects [35]. Mn in the examined meat and sausage samples occurred at mean concentration of 1.95± 0.17 ppm (ranging from 0.8 - 3.27) and 8.4± 0.97 ppm (ranging from 3.32 – 18.38), respectively. These results are higher than those reported by Alturiqi and Albedair [14] in Saudi Kingdom. Although Mn has considerable biological significance, it is quite toxic at high doses. Toxicity to humans is manifested by a psycho-logic and neurologic disorder, termed as manganism, which closely resembles Parkinson's disease [36]. No maximum was specified for Mn in foodstuffs [37].

### *3.3. Se, Cr, Ni, Cs and Fe*

Although Se was detected in all meat samples ranging from 0.79 to 2.135 ppm (with mean 1.421± 0.096), but it was found in only 2 sausage samples (1.419 and 1.197 ppm). This level of Se concentration was corresponding to that reported by Jarzyńska and Falandysz [29] in red deer in Poland. The currently recommended dietary daily intake of Se for humans is 57 µg (range 30–85 µg) but this sometimes can be insufficient for the expression of selenoprotein-P, which is considered to play a particular role in scavenging peroxynitrite and is required for the transport of Se and for certain brain functions [38]. There are many factors for which Se plays a role, and these need to be considered when deciding an optimal human supplementation with dietary Se (its species) and including a key co occurrence of vitamin E and other antioxidants but also other mineral constituents such as hazardous As, Cd and Hg

Food is the main source of chromium intake by man. Cr is fairly evenly distributed throughout the various food groups. Cr, as reviewed by Krejpcio [39], is an essential element for human and is associated with biologically active Cr (naturally occurring trivalent Cr (Cr III), while hexavalent Cr (Cr VI) doesn't occurs naturally) as a cofactor of insulin which is involved in glucose metabolism as well as in lipid and protein metabolism. Too little chromium in the diet may lead to insulin resistance. Cr (VI) compounds, have been shown to be potent occupational carcinogens [7], was found in meat and sausage samples in the present study with varying concentrations ranging from 0.37 to 2.04 ppm (with mean 1.3± 0.11 ppm) and from 0.33 to 3.44 ppm (with mean 1.13± 0.18 ppm), respectively. An adequate Cr intake is believed to be about 25 µg per day for adults and between 0.1 and 1.0 µg for children and adolescents as quoted by Rose et al. [35]. According to some other sources the adequate daily dose for children (6 years), adolescents and adults is 50–200 µg [39].

Ni was detected in all examined meat and sausage samples ranging from 0.54 to 7.45 with mean 2.25± 0.45 ppm in meat and from 1.09 to 3.71 with mean 2.22± 0.16 ppm in sausage. Demirezen and Uruc [40] reported mean Ni concentrations ranged from 8.2 to 24 µg / 100 g. According to the Institute of Medicine [41], nickel can cause respiratory problems and is carcinogenic [30]. The upper tolerable intake level of nickel for children (1–3 years old) and adults (19–70 years old) is 7 and 40 mg $d^{-1}$, respectively [41].

Cs has antagonistic properties in relation to K. At toxic doses this metal accumulates in soft tissues [33]. Although Cs was detected in al examined meat samples ranging from 0.78 to 2.42 with mean 1.6 ± 0.11 ppm, but it was undetected in sausage samples. Cs level in meat samples was corresponding to that reported in red deer muscle (1.5 mg/kg dry weight) by Jarzyńska and Falandysz [29].

Fe is considered to be the most important minor mineral in meat, especially for adult women [42]. The amount of Fe potentially available from foods, however, not only depends upon the percent of Fe present, but also on the nature of that Fe [43]. Concentration of Fe (ppm) in the present study ranged from 82.95 to 352.9 with mean 190.5± 19.43 ppm in meat and from 82.9 to 270 with mean 135.0± 10.48 ppm in sausage. Alturiqi and Albedair [14] reported higher values in sausage (242.44± 12.09 µg/g dry weight) in Saudi Kingdom. Fe in all studied samples fell within the recommended tolerable levels. The upper tolerable intake level of Fe in children (up to 8 years) and adults (14–70 years) is 40 and 45 mg $d^{-1}$, respectively [41].

### *3.4. Ag, V, Ba and Sr*

Ag was below the detection level in all meat samples but was found in only 2 sausage samples (1.049 and 1.113 ppm). Ag has a high affinity to sulfhydryl, amino and phosphate groups, and it readily complexes with many endogenous ligands of the mammalian body [29]. It is found in trace amount in animal and plant origin foods [44]. Soluble Ag in the diet is antagonistic to Se.

V was detected in meat (100%) and sausage (50%) samples with mean value± SE of 0.47± 0.04 and 0.6± 0.17 ppm. These values were greatly higher than that reported by Jarzyńska and Falandysz [29] in red deer muscle (0.026 ppm) in Poland. Merian [44] mentioned that this metal is usually found in various types of fresh food below 0.1 mg/kg but data are limited. V is thought to be an essential element that reacts with hydrogen peroxide to form a pervanadate that is required to catalyze the oxidation of halide ions and/or stimulate the phosphorylation of receptor proteins [45].

Food is the primary source of Ba exposure for the general population [46]. The possibility that Ba is an essential element has not yet been documented. Ba was detected in all examined samples ranging from 0.49 to 14.7 with mean 3.06± 0.83 ppm in meat and from 2080 to 9133 with mean 5007± 526 ppm in sausage samples. Our results were extremely higher than the mean values reported by Jarzyńska and Falandysz [29] in red deer muscle, liver and kidney (0.16, 0.12 and 0.44 mg/kg dry weight, respectively). Ba in the human body accumulates mainly in bone tissue. The daily intake of Ba for humans is about 500 µg [33], while ATSDR [46] estimated it to be slightly more than 1000 µg/day. However, the daily intake of barium is likely to vary with quantity and types of food ingested.

Sr is considered as an essential element involved in Ca and P management for animals. Nevertheless, the possibility that Sr is essential has not been confirmed. Its mean concentration in meat and sausage samples examined were 2.47± 0.84 and 11.15± 1.52 ppm, respectively. These values were extremely greater than that reported by Jarzyńska and Falandysz [29] for muscle (0.13 mg/kg dry weight), liver (0.11 mg/kg dry weight) and kidney (0.18 mg/kg dry weight) of red deer.

## 4. Conclusion

Food consumption is the major pathway for human exposure to heavy metals and so threatens the health of the population. The level of heavy metals and trace elements in beef meat and sausage in Egypt were determined and assessed by comparing the results with the permissible limits. The results indicated great variation in the concentration of the measured heavy metals and trace elements between samples. Most estimated metals indicated healthy risk as their values were higher than the permissible tolerable levels cited by internationals committees.

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