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Evaluation of trace element levels in beef cuts available to the consumers in Serbia

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Abstract. The present study evaluated the levels of Mn, Se, Cu and Zn in beef cuts available at markets in Serbia. We also assessed the risk associated with the consumption of these foods based on the estimated daily intake (EDI) of these elements. Thirty-six beef meat cuts were analysed using inductively coupled plasma mass spectrometry (ICP-MS). The EDI of all the studied elements was estimated on the basis of a calculation of the amount of beef consumed by Serbian households (mean beef consumption of 17.2 g/person/day). The studied beef cuts pose no risk with respect to the EDIs of Mn, Se, Cu and Zn. Among the four studied beef cuts, shoulder had the highest content of dietary zinc (68.2 mg/kg).

1. Introduction

The chemical hazards in food of animal origin (meat and meat products) are different [1] and they are severe public health concern all over the world. The concentrations of elements in animal tissues depend on the age and sex of animals, chemical composition of meat, sampling season (hunting), and nutrition [2-4]. In recent years, concern has arisen in the EU regarding adjustment of mineral supplementation to actual physiological needs of animals, as large loads of trace elements (mainly Cu and Zn) are occurring in the environment [5].

On the other hand, it is common knowledge that consumption of meat has been an important component of the human diet for a long time, as it provides highly bioavailable elements required for normal development and health [6, 7]. In this context, meat is an important source of energy and nutrients, including proteins, minerals (manganese (Mn), zinc (Zn), copper (Cu), iron (Fe) etc.) and vitamins (B12, folic acid). Minerals contained in meat, in comparison with those present in plants, are more easily absorbed [8]. Consequently, the determination of essential elements in all types of food, including meat and meat products, is necessary for quality assurance and consumer health protection.

Meat consumption is based largely on availability, price and tradition. The consumption data of meat and meat products worldwide are presented in Table 1 [9]. In Serbia, poultry is the most commonly consumed meat type per capita (18.7 kg), followed by pork (18.5 kg) and beef (6.3 kg) in 2019 [10].

Mn, selenium (Se), Cu, Zn and other major elements are essential micronutrients that need to be consumed in adequate amounts to maintain normal physiological function [11]. Small quantities of these elements are vital for growth and development and they can be obtained through a balanced diet. [12]. Mn is a cofactor for many enzymes and it is involved in amino acid, cholesterol, and glucose and other carbohydrate metabolism [13]. Se is a constituent of more than two dozen selenoproteins that play critical roles in reproduction, thyroid hormone metabolism, DNA synthesis and protection from

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oxidative damage and infection [14]. Cu is a cofactor for several enzymes (known as cuproenzymes) involved in energy production, iron metabolism, neuropeptide activation, connective tissue synthesis and neurotransmitter synthesis [15]. Zn is involved in numerous aspects of cellular metabolism, supports normal growth and development during pregnancy, childhood, and adolescence and is required for proper sense of taste and smell [16].

Table 1. Meat consumption worldwide and by continent in 2017 [9]

	Meat Consumption (kg/per capita/year)*				
Type of Meat	World	Africa	America	Asia	Europe
Bovine	9	5.63	27.83	4.68	14
Mutton and goat	1.86	2.49	0.62	1.93	1.75
Pork	15.7	1.48	18.65	15.18	35.75
Poultry	15.18	6.21	41.94	9.71	24.59
Others	0.84	1.43	0.65	0.55	1.84
Total	42.58	17.24	89.69	32.05	77.93

The lack of information on the concentrations of trace elements in beef cuts in Serbia was the main reason to carry out the present study. In this context, this work evaluated the levels of Mn, Se, Cu and Zn in such food. The obtained results were compared with the literature data from other countries. In order to assess exposure to trace elements through the consumption of beef cuts, the daily and weekly intakes were calculated and compared with the nutritional limits.

2. Materials and Methods

2.1. Sample collection

A total of 36 different beef cuts (beef steak, hind leg, shoulder and neck) commercially available in Serbia were collected during 2020. After collection, meats were labelled and stored in polyethylene bags and frozen at -18°C prior to analysis.

After acid mineralization of homogenized beef cuts, microwave digestion (Digestion System: Milestone, Sorisole, Italy) was used for sample preparation. Analysis of Mn, Se, Cu and Zn was performed by inductively coupled plasma mass spectrometry (ICP-MS), (iCap Q mass spectrometer, Thermo Scientific, Bremen, Germany). The most abundant isotopes were used for quantification. The accuracy of the analysis was verified by analysing the certified reference material NIST SRM 1577c (bovine liver, Gaithersburg, MD, USA).

2.2. Estimated daily intake

Nutritional exposure to the examined trace elements was calculated by estimation of the daily intake (EDI). The daily intake (DI) of each measured element in beef cuts was calculated used the following equation:

$$DI\ (mg) = [D\ (g) \times C_{element}\ (mg\ kg^{-1})]/1000$$

where DI is the daily intake (mg), D is the average Serbian per capita daily consumption of beef (17.2 g) [10] and $C_{element}$ is the concentration of element (mg kg^{-1}) detected in beef cut.

EDIs were expressed in mg/kg bw day was calculated according to the following equation:

EDI = DI (mg) / kg bw = mg/kg bw day

where bw is individual's body weight (bw; assumed to be 70 kg).

The calculation of the EDI is the same as the provisional maximum tolerable daily intake (PMTDI). The PMTDI value is the permissible human exposure of a substance in food and drinking water [17]. Hazard quotients (HQs) for Mn, Se, Cu and Zn in the analysed samples were calculated according to the following equation:

$$HQ\ [\%] = [EDI_{calc} / PMTDI] \times 100$$

where EDI_{calc} is the EDI found in this study, and PMTDI is the established provisional maximum tolerable daily intake (PMTDI) (Table 2)

Table 2. Provisional tolerable weekly intake (PTWI) and provisional maximum tolerable daily intake (PMTDI) of essential elements (Mn, Se, Cu and Zn)

Elements	PTWI	PMTDI	References
Mn	49.7 µg/kg bw/week	500 µg/day (7.1 µg/kg bw/day)*	NRC, 1989 [18]
Se	30.1 µg/kg bw/week	300 µg/day (4.3 µg/kg bw/day)	EFSA, 2006 [19]
Cu	3.5 mg/kg bw/week	0.5 mg/kg bw/day	WHO, JECFA, 26 (1982) [20]
Zn	7 mg/kg bw/week	1 mg/kg bw/day	WHO, JECFA, 26 (1982) [20]

*bw – assumed to be 70 kg

3. Results and discussion

3.1. Levels of Mn, Se, Cu and Zn in four beef cuts

The results obtained for Mn, Se, Cu and Zn levels in four different beef cuts are presented in Table 3.

Table 3. Mn, Se, Cu and Zn levels (mean ± SD*) in selected pork cuts

	Beef cut	n**	Levels (mg/kg) Mn	Se	Cu	Zn
1	Beef steak	7	0.110±0.049	0.088±0.052	0.783±0.206	46.068±17.335
2	Hind leg	16	0.131±0.054	0.179±0.054	0.743±0.310	42.286±14.616
3	Shoulder	6	0.126±0.061	0.081±0.051	0.826±0.164	68.165±15.119
4	Neck	7	0.146±0.050	0.088±0.045	0.829±0.282	58.055±16.016

*SD – standard deviation; **n – number of samples

The lowest and the highest Mn levels, respectively, in beef cuts were 0.110 mg kg^{-1} in beef steak and 0.146 mg kg^{-1} in neck. Mn contents in the literature have been reported in the range of 0.076-0.15 mg kg^{-1} in beef cuts [21] and 0.10-1.6 mg kg^{-1} in beef, beef with vegetables and beef breakfast samples [22].

The level of Se in beef cuts from this study was in the range 0.081-0.179 mg kg^{-1}. Se contents in the literature have been reported in similar ranges. Bilandžić at al. [21] established the Se level as between

0.087 mg kg^{-1} (neck) and 0.21 mg kg^{-1} (shoulder) in different beef cuts. Se contents in beef meat products have been reported in the range of 0.08-0.8 mg kg^{-1} [22, 23].

The Cu levels in beef cuts (0.743-0.829 mg kg^{-1}) in this study were close to Cu levels in beef cuts available to the population in the Croatian capital (0.61-0.84 mg kg^{-1}) [21]. De Sousa Ramos et al. [24] established the Cu content was 0.883 mg kg^{-1} in beef hamburger. Similar Cu levels were established in beef with vegetables (0.89 mg kg^{-1}) and beef breakfast (0.71 mg kg^{-1}) [22].

Beef is considered to be a source of Zn with very high bioavailabity [25], although the zinc level depends on the meat cut. This study showed that the lowest and the highest Zn levels, respectively, in beef cuts were 42.286 mg kg^{-1} in hind leg and 68.165 mg kg^{-1} in shoulder. In the literature, Zn levels in beef cuts varied between 38.8 and 56.3 mg kg^{-1} [21, 22, 24, 26].

3.2. Daily intake (DI) of trace elements

The average DI (µg/day) of Mn, Se, Cu and Zn estimated for the four beef cuts for an adult in Serbia are reported in Table 4.

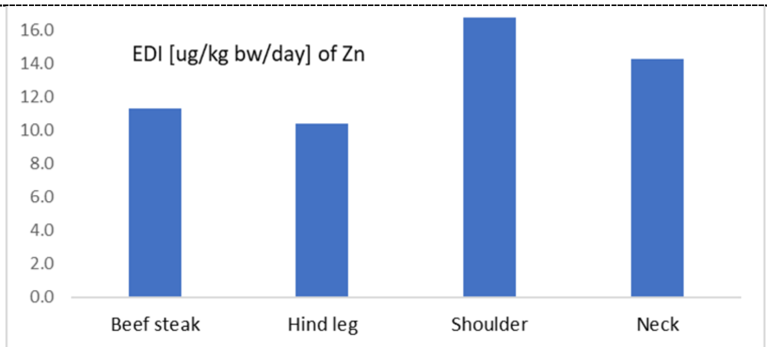
Table 4. Dietary intake, DI (µg/day) of the trace elements Mn, Se, Cu and Zn in beef cuts

	Dietary intake, DI (µg/day)			
Beef cuts	Mn	Se	Cu	Zn
Beef steak	1.892	1.514	13.468	792.370
Hind leg	2.253	3.079	12.780	727.319
Shoulder	2.167	1.393	14.207	1172.438
Neck	2.511	1.514	14.259	998.546

The mean average DI was 2.21, 1.88, 13.68 and 922.67 µg/day for Mn, Se, Cu and Zn, respectively. In the case of Zn, beef shoulder provides the highest intake of this element out of the four selected beef cuts (1172.438 µg/day). However, the DI of Se was the lowest from shoulder (1.393 µg/day), whereas the highest DIs of Mn and Cu were from neck.

3.3. Estimated daily intake (EDI) and hazard quotients (HQs) of trace elements

Figure 1 shows the EDI of Mn, Se, Cu and Zn, and their comparisons, considering the average Serbian per capita consumption of beef (17.2 g/person/day) [10].



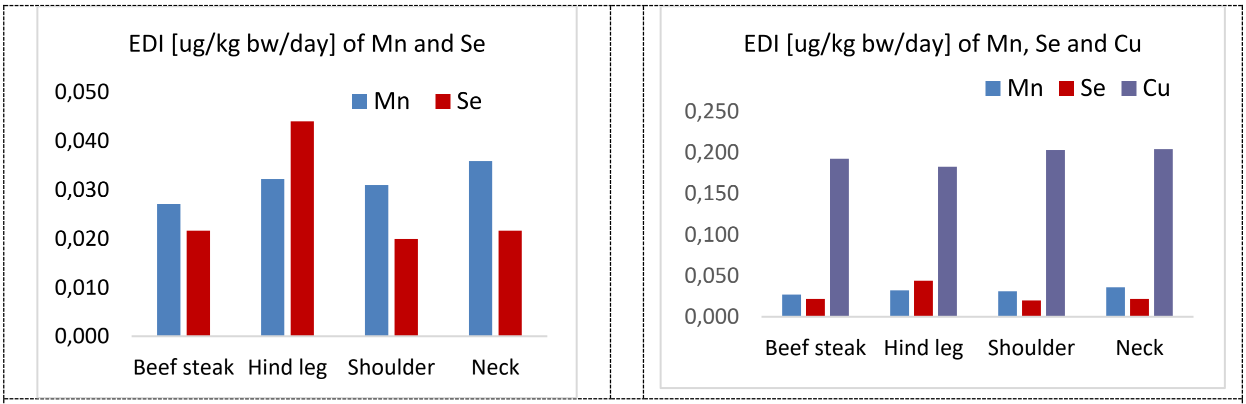


Figure 1. Estimated daily intake (EDI) of Mn, Se, Cu and Zn and their comparisons.

The findings of this study show that the EDIs (μg/kg bw/day) of the analysed trace elements differ widely. It is not possible to directly compare our EDI to those reported in the literature since our study was based on the intake from only one type of food. Among the four beef cuts in this study, shoulder had the highest content of dietary Zn (68.2 mg/kg) and, consequently, the highest EDI (Figure 1). EDIs for Mn and Se fell in a similar range, while the EDI of Cu was from six- to ten-fold higher than EDIs for Mn and Se.

Table 5 shows the hazard quotients (HQs) of Mn, Se, Cu and Zn, expressed as % of the calculated EDI in this study out of the PMTDI, recommended values set by NRC, EFSA and WHO (Table 2).

Table 5. Hazard quotients (HQs) of the trace elements Mn, Se, Cu and Zn

	Hazard quotient, HQ (%)			
Beef cuts	Mn	Se	Cu	Zn
Beef steak	0.38	0.50	0.04	1.13
Hind leg	0.45	1.02	0.04	1.04
Shoulder	0.44	0.46	0.04	1.67
Neck	0.51	0.50	0.04	1.43

The HQs obtained were between 0.04 % (in all four beef cuts) and 1.67% (Zn, shoulder). This shows that the obtained EDIs of Mn, Se, Cu and Zn, which refer to beef consumption by the Serbian population, are much lower than the provisional maximum tolerable daily intakes (PMTDI). Hence, element levels in examined four beef cuts were within safe limits.

4. Conclusion

This is a rare study to have determined the intake of trace elements (Mn, Se, Cu and Zn) from beef in the population in Serbia. The levels of the four elements in commonly consumed beef cuts (beef steak, hind leg, shoulder and neck) were determined. The results obtained show trace element ingestion from beef sources was acceptable for human consumption at nutritional levels.

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