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TOXIC HEAVY METALS CONTENT IN WILD BOAR AND VENISON MEAT: A BRIEF REVIEW

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Abstract

Heavy metals are prevalent in the environment and often are encountered in the food supply chain. Their presence in large game meat is commonly caused by environmental pollution and hunting techniques (ammunition for hunting), and the intake of such contaminated sub-products has demonstrated an adverse effect on consumers 'health. Regularly, the literature makes risk assessments of specific consumption scenarios regarding possible health risks to extreme game meat consumers (i.e. hunters and their family members). Therefore, tracking this metals concentration in game meat and the updated situation (especially Cd, Pb) is necessary to ensure compliance with food safety regulations and consequent consumer and environmental protection, reason for which this review addresses various gaps in current awareness (knowledge and research) on the accumulation of metal pollutants in commercially processed and consumed big game meat worldwide.

Key words: *heavy metals, game meat, contamination.*

INTRODUCTION

Heavy metals are ubiquitous in the ecosystem and can enter the food chain. Them are predominantly transferred as molecules or particulate matter via the atmosphere, mostly over distances. The amount of anthropogenically generated heavy metals has slowly increased since the beginning of the industrial revolution, but in recent decades public understanding and awareness associated with their environmental and health risks has risen sharply (Pilarczyk et al., 2020).

Heavy metals become harmful because they tend to bioaccumulate (i.e. the concentration of metal in a biological organism will increase relative to its environmental concentration over time) because the compounds accumulate in living organisms at any time they are consumed and stored faster than they are metabolized or excreted (Pascoe et al., 1994). Consequently, eating contaminated products will adversely affect consumer health. Due mainly to their persistence and biomagnification across the food chain, exposure to these chemical contaminants is of particular concern.

Specific environmental and biological parameters affect the transfer of this pollutants from the atmosphere to biota (Baker et al., 2003). The impact of gender on bioavailability, transmission and effects of contaminant has been shown (Baker et al., 2003; Gonzalez et al., 2008; Fritsch et al., 2010; Tchounwou et al., 2012). For monitoring purposes, the literature covers specific food chain levels, such as primary (herbivorous) and secondary (carnivorous) consumers (Sánchez-Chardi et al., 2009). The study of wildlife species in anthropogenic habitats that may be changed or damaged provides important information about the viability and equilibrium of the ecosystems. Moreover, the use of natural populations as environmental pollution sentinels helps to increase our awareness and strengthen the response to environmental and human health issues (Alleva et al., 2006).

This paper will address toxicological reference values for selected heavy metals (Cd and Pb), documented to occur in game meat (wild boar and venison) and relevant to human health.

Toxicological reference value and maximum level for Cd and Pb

Legislation controls the highest permissible levels of certain contaminants, including certain food elements. In the E.U., the maximum levels for certain contaminants in foodstuffs are determined by Commission Regulation (EC) (2008).

Cadmium

There is no maximum EU-regulated level of Cd in game meat. For Cd food intake, the EFSA CONTAM Panel published a tolerable weekly intake (TWI) of 2.5 μg/kg body weight (bw), although the ICRA classified it as human cancer based on occupational studies (EFSA, 2009); also, for livestock meat products (excluding offal of bovine, sheep, pig and poultry), the maximum level for cadmium is 0.05 mg/kg (EC, 2006).

Cereals and cereal sub products, vegetables, nuts and pulses, starchy roots and meat or meat products are the main contributors to dietary cadmium intake. Mean dietary intake in Europe was estimated to be 2.3 μg/kg bw/week (from 1.9 to 3.0 μg/kg bw/week), a range with upper limits slightly higher than TWI of 2.5 μg/kg bw. Population subgroups, such as vegetarians, children, smokers and people living in highly contaminated areas may exceed the TWI (EFSA, 2009).

Lead

There is no maximum EU-regulated level of Pb in game meat. In 2010, the European Food Safety Authority (EFSA, 2010) evaluated the health effects of lead in food (developmental neurotoxicity for children, respectively cardiovascular effects and nephrotoxicity for adults). Since no safe Pb intake levels could be determined, EFSA revoked the toxicological limit of 25 μg lead per kg bw/week in food and stated that any lead intake should be as minimal as reasonably achievable for humans in accordance with the ALARA principle. EFSA established lead toxicological reference values using the Benchmark Dose (BMD) framework and calculated the resulting dietary lead accumulation for: developmental neurotoxicity (0.50 μg/kg body weight per day), systolic blood pressure (1.5 μg/kg bw per day) or for prevalence of CKD (0.63 μg/kg bw per day).

In general, the exposure of the consumer to lead is primarily due to the intake of food with a relatively low lead content but with high consumption rates (i.e. fruit, vegetables and tap water). Game meat is a food item that is rarely consumed by the majority of the general population but is consumed by specific subgroups (i.e. hunter family members).

Cadmium and lead occurence in selected game meat

Across Europe, cadmium and lead have been included in monitoring programs because they are toxic and not at all essential to animals or human health. In the same time, game species are used as strong bioindicators for toxic metal emissions in biomonitoring studies (Santiago et al., 1998; Millan et al., 2008; Pérez-López et al., 2016). Mammals such as wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*) and red deer (*Cervus elaphus*) are excellent bioindicators of the degree of heavy metal pollution in the environment (Amici et al., 2012; Bakowska et al., 2016; Srebočan et al., 2011; Mitrănescu et al., 2011; Lazarus et al., 2014). As the obtained values are specific to game species, the wildlife conditions, the method of harvesting, the study hypothesis, Tables 1 and 2 summarize the levels of the most important investigations concerning contamination of wild boar and venison meat.

The transfer of heavy metals to animal tissues occurs primarily through the digestive tract due to ingestion of feed containing either heavy metals or soil polluted. Their concentration in free-living animals depends on a number of factors related to the area of residence, the properties of the soil, the characteristics of the species, the physiological status of the plants, the lifestyle and diet of the animals and their location relative to industrial plants.

Of all the game species mentioned above, wild boars are considered most appropriate as bioindicators due to their abundance in almost all regions of Europe, both in agricultural and forest areas. In addition, wild boars are omnivorous animals. Although 80-90% of their diet includes food retrieved from the soil (acorns, beech, nuts, herbs, grass, roots, rhizomes, or earth-worms), they also eat insects, frogs, eggs, chicks, rodents, and carrion (2-11%) (Schley and Roper, 2003; Baubet et al., 2004).

Table 1. Concentration of some heavy metals [Cd, Pb (μg g^{-1} ww)] in venison (mean value)

CC	Cd	Pb	References
Muscle tissue	1.0	0.8	Świergosz et al., 1993
	1.0	1.5	Falandysz and Gadja, 1988
	1.7	1.7	Falandysz, 1994
	3.4	2.3	Rimkus and Wolf, 1987
	0.46	0.652	Pilarczyk et al., 2020
	2.2	1.8	Jarzynska and Falandysz, 2011
	0.254^{LA}	2.079^{LA}	Mitranescu et al., 2011
	0.119	1.25	Taggart et al, 2011
	0.06	0.79	Gizejewska et al., 2017
	0.04/0.01/0.07/0.03	0.059/0.057/0.561/0.062	Bilandzic et al., 2009*
	0.43/0.05/0.07	0.57/0.26/0.12	Durkalec et al., 2015*
		$0.42^{M}/0.55^{F}$	Lehel et al., 2016
Animals offal	2.1		Falandysz, 1994
		0.21/0.71/0.11/0.55	Pokorny, 2000*
	0.19/0.15/0.11/0.20	0.11/0.08/0.77/0.07	Bilandzic et al., 2009*
		0.17	Jarzynska and Falandysz, 2011

CC = contamination category; **x** = processed data; **RV** = recommended value, **IV**= identified value; Gender **M** = male, **F** = female; **LA** = allowed limits according to Regulation (EC) no. 1881/2006; **I, II, III** = different age categories; ***** = different grounds of research.

Table 2. Concentration of some heavy metals [Cd, Pb (μg g^{-1} b.w.)] in wild boars (mean value)

CC	Cd	Pb	References
Muscle tissue	0.45	0.73	Hecht, 1986
	2.4	1.2	Rimkus and Wolf, 1987
	1.3	1.6	Falandysz and Gadja, 1988
	0.30	3.5	Venalainen, 2007
	0.11	0.316	Taggart et al, 2011
	0.79	0.126	Amici et al., 2012
	0.78^{x}	1.24	Danieli et al., 2012
	0.15	3.273	ANSES, 2018
	0.53	0.66	Pilarczyk and colab., 2020
	1.12^{RV} / 1^{IV}	$4.91^{RV}/4.8^{IV}$	Falandysz, 1994
	$0.3^{M}/0.2^{F}$	$0.13^{M}/0.10^{F}$	Roslewska et al., 2016
	$0.440^{LA}/0.310^{LA}$	$0.821^{LA}/0.504^{LA}$	Mitranescu et al., 2011
	$0.08^{I}/0.14^{II}/0.17^{III}$	$0.42^{I}/0.53^{II}/0.82^{III}$	Rudy, 2010
	0.23/0.01/0.05	1.95/1.06/0.83	Bilandzic et al., 2009*
	0.107/0.209/0.205	1.46/1.799/1.425	Florijancic et al., 2015*
	0.40/0.04/0.04	0.46/0.19/0.27	Durkalec et al., 2015*
	0.6/19.8	0.8/0.9	Świergosz et al., 1993*
Animals offal	0.49/0.32/0.30	1.2/0.62/2.02	Bilandzic et al., 2009*
	2	4	Rudy, 2010
	0.84^{x}	3.29	Danieli et al., 2012
	0.85	3.18	Amici et al., 2012
	0.326	3.83	Neila et al., 2017

CC = contamination category; **x** = processed data; **RV** = recommended value, **IV**= identified value; Gender **M** = male, **F** = female; **LA** = allowed limits according to Regulation (EC) no. 1881/2006; **I, II, III** = different age categories; ***** = different grounds of research.

Heavy metals are partially taken up by wild boars due to the ingestion of earthworms that produce substantial quantities of lead and other heavy metals in their tissues (Latif et al., 2013). Also, drawing the soil clods while grazing (also known as rooting) may also play a decisive role in this process (Bakowska et al., 2016).

Unlike other food products, game meat has an additional entry for heavy metals due to hunting ammunition (Dobrowolska and Melosik, 2008; Müller-Graf et al., 2017; Taggart et al., 2011; Tsuji et al., 2009), sporadically, game meat showing higher levels of lead among analysed items (EFSA, 2010).

Literature data reveals that game meat of animals shot with lead-based ammunition contains more lead than game meat obtained with nonlead ammunition because lead bullets split into small lead particles on impact and produce fine lead splinters (Hecht, 2000; Müller-Graf et al., 2017). Various researches approach the impact of age and gender on game meat lead content. Thus, Srebočan et al. (2012) states that the highest concentration of lead observed in the muscle tissues of young animals (roe deer and wild boar) is attributed to their potential need for minerals, since calcium kinetics are strongly linked to lead kinetics.

The lead distribution within the game meat is also examined, the highest lead concentrations being found closest to the wound in game meat of roe deer, red deer and wild boar with a maximum of 4.7 mg/kg, 3.4 mg/kg, 1.6 mg/kg, respectively, when lead containing ammunition was used (BfR, 2014).

Other experiments also reported a decrease in the lead concentrations with increasing distance from the wound channel in game meat of red deer, wild boar and white-tailed deer (Dobrowolska and Melosik, 2008; Grund et al., 2010). They analysed muscle and soft tissue of red deer and wild boar for lead content immediately after being killed at different distances (5, 15, 25 and 30 cm) from the wound channel. Lead particles at a distance of 30 cm from the entry wound were detected in each sample. The highest lead content was 1095.9 mg/kg near the wound channel in a sample of wild boar meat and 3.3 mg/kg, 30 cm away from the entry wound. All animals were killed with lead-based ammunition (Dobrowolska and Melosik, 2008). In the second case, lead contamination levels in muscle tissue samples from white-tailed deer at different distances from the wound channel (5, 25 and 45 cm) were analysed. Detectable lead concentrations were found at all distances, and the highest concentrations were found closest to the wound channel (Grund et al., 2010).

Lead levels of red deer meat, in concordance with origin country are summarized in Table 3 (Froslie et al., 1984; Michalska et al., 1992; Wolkers et al., 1994; Falandysz, 1994; Drozd et al., 1997; Kottferová et al., 1998; Santiago et al., 1998; Szkoda et al., 2001; Szymczyk, 2001; Falandysz et al., 2005; Lazarus et al., 2005; Kramárová et al., 2005; Vikoren et al., 2005).

Table 3. Lead levels (mg/kg b.w.) in red deer meat from various countries (Venäläinen, 2007)

	Muscle	Liver	Kidney
NL		0.193-0.122	0.449-0.386
PL	0.09 – 0.39	0.11-0.70	0.14-0.38
ES		0.57	0.33
HR			0.58
SK	0.35	0.32-1.90	0.48-0.56

NL = Netherlands, **PL** = Poland, **ES** = Spain, **HR** = Croatia, **SK** = Slovakia.

In the case of wild boars harvested from Croatia hunting grounds, a number of research studies have obtained almost similar values for Cd content, as follow: 0.01-0.23 mg kg^{-1} (Bilandžić et al., 2009), 0.005-0.062 mg kg^{-1} (Bilandžić et al., 2010), results close to the values (0.02 mg kg^{-1}) previously reported by Michalska and Żmudzki (1992), specific to free-living wild boars from the Wielkopolska region of Poland. Moreover, the highest concentrations of Cd (0.56 mg kg^{-1}) were found to accumulate in kidneys (Roślewska et al., 2016), because this organ is essential for the excretion of toxins from the body (Drozd et al., 2001). This was a confirmation of previous Cd accumulation surveys described earlier in wild boars from Slovakia by Gasparik et al. (2012) for the kidney, liver and muscles.

Heavy metals, especially Cd and Pb, accumulate in animal organs. Analyses of different organs showed that the highest amounts of Pb (0.39 mg kg^{-1}) were accumulated in kidneys (Piskorová et al., 2003). In wild boar muscles and liver increases with age, with only the category of youngest and oldest animals considered statistically significant differences, but with values without reaching the maximum legal level (i.e. for lead (0.045 for the youngest specimens and 0.087 mg kg^{-1} for the oldest animals) or cadmium (0.011 for the youngest and 0.018 mg kg^{-1} for the oldest animals) content (Rudy, 2010).

Different outcomes have been obtained by Szkoda and Żmudzki (2001), showing that the average lead content of wild boar meat ranged from 0.121-0.437 mg kg^{-1}, exceeding the maximum permissible level in over 20% of the samples, possible to the lead intoxication from gunshot wounds (Dobrowolska and Melosik 2008). For such a justification, muscle tissue should not be considered a valid predictor for the degree of ecosystem contamination by this element.

A recent study on the problem of heavy metals in western Ukraine shows that despite continuous emission reductions, the environment still contains high concentrations of toxic elements (Pilarczyk et al., 2020).

CONCLUSIONS

Contamination of game meat with selected heavy metals (Cd, Pb) poses a risk to human health and undermines food safety worldwide; the most common methods used in literature are risk assessments of specific consumption scenarios to provide effective mitigation methods for reducing concentrations of contaminants, game meat being a useful tool.

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