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EFFECT OF SEX ON THE CONTENT OF ELEMENTS IN MEAT FROM WILD BOARS (*SUS SCROFA* L.) ORIGINATING FROM THE PROVINCE OF PODKARPACIE (SOUTH-EASTERN POLAND)

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Abstract

The aim of the study was to determine concentrations of some elements, incluing minerals and heavy metals (Na, K, Mg, Zn, Fe, Cu, Cd, Pb), in the meat (*musculus longissimus dorsi*) of the wild boar (*Sus scrofa* L.) depending on the sex of the animals. The wild boars were shot during the hunting 2011-2012 season, in the Province of Podkarpacie (*województwo podkarpackie*), Poland. Podkarpacie, situated in south-eastern Poland, is known for its variety of wildlife living in natural habitat. The study involved 16 animals (8 of each sex) aged 2 years. Meat samples were freeze-dried (Lyovac GT2, Finn-Aqua) and then mineralised in a microwave mineraliser (Ethos Plus, Milestone). Samples prepared in this way were later analysed for the concentration of minerals, using various techniques. The content of heavy metals (Cd and Pb) was determined by atomic emission spectroscopy, while the levels of other elements (Na, K, Mg, Zn, Fe and Cu) were assayed using an atomic absorption spectrometer. The analyses indicated no significant statistical differences between males and females in the quantity of most metals in their bodies, except copper (Cu), whose average amount was higher in meat samples from females (7.5 mg kg^{-1}) than from males (6.15 mg kg^{-1}) – $p \leq 0.01$. The determinations of heavy metals revealed that the average lead (Pb) concentration exceeded the acceptable limit only in meat samples from males (0.13 mg kg^{-1}). When examining the levels of minerals in wild boar meat, a positive and statistically significant correlation was found only between the average quantities of K and Mg.

Keywords: wild boar (*Sus scrofa* L.), meat, elements, heavy metals.

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INTRODUCTION

Studies on the mineral content of meat from wild animals are interesting because their results can be viewed in different contexts. One aspect pertains to the growing interest in natural, organic and healthy foods with no added growth stimulants, which makes meat of wild animals becoming increasingly popular among consumers around the world. Game is a rich source of high-value protein, unsaturated fatty acids, as well as vitamins and minerals, including iron, copper and zinc, which can be more easily absorbed and more useful to the human body than plant minerals (Ziembińska, Krasnowska 2007, Skobrak et al. 2011, Laird, Chan 2013). The nutrient content of meat can be influenced by many factors such as animal species, age and sex, and environmental factors (Lombardi-Boccia et al. 2005, Greenfield et al. 2009, Tomović et al. 2011).

Because they are perfectly integrated with their natural habitat, game animals may serve as an objective indicator of the extent of environmental contamination. Soil, climate and man-made changes such as fertilisation, industrial pollution and mechanical treatment, which change the edaphic and physicochemical characteristics of soil, have an effect on the mineral content of browse and herbaceous plants (Drozd et al. 2003). Because of the feeding habits, mode of life and constant movement of wild boar, its meat may act as a good indicator of the environmental contamination with heavy metals such as cadmium and lead, radioactive metals, pesticides and polychlorinated biphenyls (Szkoda, Żmudzki 2001, Kucharczak et al. 2003, Sales, Kotrba 2013), which may limit the edibility of their meat. Exposure to harmful substances is most often associated with their accumulation in animal bodies and may negatively affect the nervous, endocrine, reproductive or vascular function.

The aim of the study was to determine the content of some minerals and heavy metals in the meat of wild boars with regard to their sex.

MATERIAL AND METHODS

The experiment was performed on meat samples from 16 wild boars (*Sus scrofa* L.), 8 of each sex, originating from Podkarpacie, which is the south-easternmost province of Poland (Figure 1). This area is characterised by relatively low environmental pollution. The results of long-term studies have confirmed that the region is in good ecological condition. The province's high forest coverage and large areas submitted to various forms of nature conservation provide conditions for sustainable development. This region is located in the third climate zone and is characterised by an annual average ambient temperature of 7.6°C and an average annual rainfall above 650 mm.

Anthropogenic activity is the main source of atmospheric pollution in Podkarpacie. The largest amounts of pollutant gases and particulates reach the atmosphere from energy fuel combustion emissions. Yet, the annual average concentrations of sulphur dioxide in the province remained low in 2000-2007. During that period, air monitoring stations did not detect any exceedance of imission standards set for sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone and benzene (Provincial Environmental Inspectorate in Rzeszów. The state of the environment in the Province of Podkarpacie in 2000-2007). In 2011, the imission standards for suspended particulates were exceeded in three areas of the province: Rzeszów, Krosno, and Przemyśl and Jasło (Provincial Environmental Inspectorate in Rzeszów. The state of the environment in the Province of Podkarpacie in 2011).

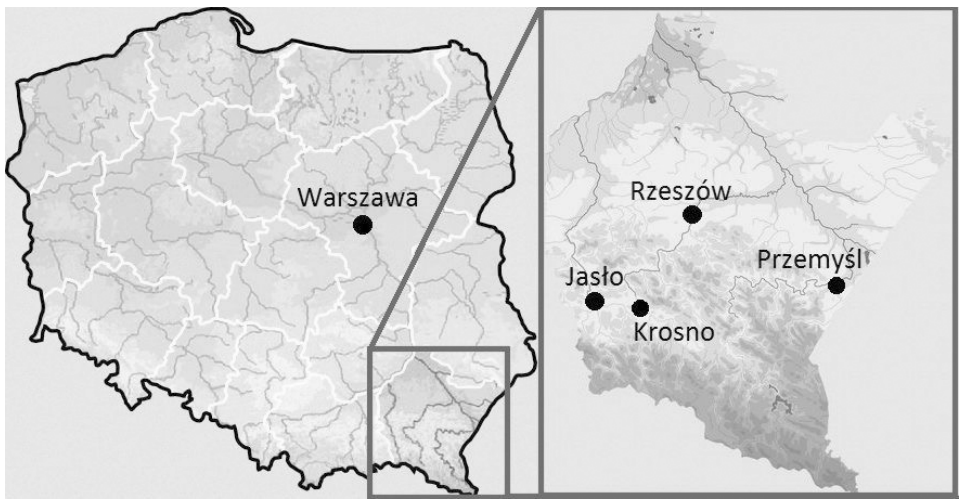

Fig. 1. The map of Poland and the localization of the study area

The wild boars were shot by individual hunters during the 2010-2011 hunting season, in compliance with Regulations No 45 and No 48 of the Minister of Environment (2005). Samples of *musculus longissimus dorsi* were collected from 2-year-old boars weighing on average 47 kg (range 39-59 kg for males and 37-62 kg for females), placed in sterile, tightly sealed zipper bags and cooled to 4°C. Upon delivery to the laboratory, samples were freeze -dried in a Lyovac GT2 lyophilizer (Finn-Aqua).

To determine selected minerals (Na, K, Mg, Zn, Cu, Fe), 0.2 g of freeze -dried tissue was weighed, a mixture of HNO_3 and H_2O_2 at a 4:1 ratio was added and the sample was wet mineralised for 20 min in an Ethos Plus microwave mineralizer (Milestone) at 190°C. Mineralised samples were transferred to 50 cm^3 volumetric flasks and analysed using Atomic Absorption Spectrometer (SOLAR 969, UNICAM, England).

In order to determine the content of heavy metals (Pb and Cd), 2 g of

tissue was weighed into a quartz evaporating dish and dry mineralized in a muffle furnace. Tissues were precarbonised and the analysed samples were burned for approx. 16 h at a temperature lower than 450°C. The ready samples were analysed by ICP-AES, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES Jobin Yvon JY 38S HORIBA). The mineral content was expressed as mg per kg of fresh tissue.

Arithmetic means and standard deviation were calculated. Significant differences between sexes were evaluated by the Tukey's test. Statistical calculations were done using Statistica 6.0.

RESULTS AND DISCUSSION

Table 1 presents an average content of different elements in the samples of wild boar meat. The highest content was determined for macrominerals: sodium (920 mg kg^{-1}), potassium (14 780 mg kg^{-1}) and magnesium (910 mg kg^{-1}). These values were slightly higher in males than in females, in which they amounted to 770, 14 650 and 870 mg kg^{-1}, respectively. The results did not differ significantly. In turn, smaller amounts of zinc (61.28 mg kg^{-1}), iron (165.72 mg kg^{-1}) and copper (6.15 mg kg^{-1}) were noted in the muscles of males compared to females, the meat of which contained 68.21, 217.04 and 7.54 mg kg^{-1} of zinc, iron and copper, respectively.

The cadmium content of meat was 0.03 mg kg^{-1} in males and 0.02 mg kg^{-1} in females. Lead was more abundant in the meat of males (0.13 mg kg^{-1}) than females (0.10 mg kg^{-1}). However, no statistically significant differences in the cadmium and lead content of meat were observed between males and females ($p \geq 0.05$).

Wild boar meat may contain more mineral elements than meat from farm animals, including pig meat (Kirchgessner et al. 1994, Lombardi-Boccia et al. 2005). The samples of meat from male and female wild boar were reported to contain much more sodium and potassium compared to the muscles of pigs (Greenfield et al. 2009). In the meat of wild boars from the Slovak Republic, the Na and K content averaged 609 and 3287 mg kg^{-1}, respectively, and was lower than in meat from pigs – 940 and 3590 mg kg^{-1} (Sales, Kotrba 2013). In the meat of wild boar pig hybrids (*Sus scrofa ferus* × Duroc pig) from Wronie (Poland), the sodium and potassium content ranged from 188.3 to 224.4 and from 1322.6 to 1798.3 mg 100 g^{-1}, respectively (Kapelański et al. 2007).

The present study showed that magnesium levels were higher in meat from males compared to females (Table 1). Similar relationships were reported by Skobrak et al. (2010). Furthermore, the content of this element in meat from the investigated wild boars was higher than the values determined by Długaszek, Kopczyński (2013) – 250 µg g^{-1}, Sales, Kotrba (2013) –

Table 1

Mineral compounds and heavy metal content in the meat of wild board (*Sus Scrofa* L.) from the Province of Podkarpacie

Minerals/heavy metals (mg kg^{-1})		Males	Females
Na	x min-max SD	920^{A} 780-1170 14	770^{A} 420-1230 31
K	x min-max SD	$14\ 780^{A}$ 12 850-17 250 159	$14\ 650^{A}$ 12 040-18 730 218
Mg	x min-max SD	910^{A} 830-1030 8	870^{A} 810-1060 6
Zn	x min-max SD	61.28^{A} 48.60-80.60 12.67	68.21^{A} 40.90-106.10 23.59
Fe	x min-max SD	165.72^{A} 96.40-360.60 98.19	217.04^{A} 139.6-286.10 52.27
Cu	x min-max SD	6.15^{A} 5.20-6.80 0.56	7.5^{B} 6.50-9.20 0.90
Cd	x min-max SD	0.03^{A} 0.01-0.06 0.02	0.02^{A} 0.01-0.05 0.01
Pb	x min-max SD	0.13^{A} 0.09-0.18 0.03	0.10^{A} 0.06-0.12 0.03

Values marked in the same row with different letters (*A*,*B*) are statistical significantly different at $p \leq 0.01$; x – mean; SD – standard deviation

269 mg kg^{-1} Skobrak et al. (2010) – from 221.4 to 232.1 mg kg^{-1} and Skobrak et al. (2011) – from 187.6 to 259.7 mg kg^{-1}. In the meat of wild boar pig, the magnesium content ranged between 107.2 and 144.4 mg 100 g^{-1} (Kapelański et al. 2007).

The concentrations of zinc, iron and copper in the meat of wild boars from the Province of Podkarpacie were lower for males than females (Table 1). Similar results were obtained by Skobrak et al. (2010). The average Zn, Fe and Cu content of meat was 43.8, 45.0 and 1.64 mg kg^{-1} for males, and 45.5, 49.3 and 1.85 mg kg^{-1} for females, respectively.

The average content of zinc in the meat of the wild boars demonstrated in our study was similar to the values reported by Kucharczak et al. (2003), which ranged from 44.57 to 62.29 mg kg^{-1}, but were higher than those

obtained by Michalska, Żmudzki (1992) – from 26.1 to 28.0 mg/kg, Skobrak et al. (2010) – from 43.8 to 45.5 mg kg^{-1} and Skobrak et al. (2011) – from 37.9 to 52.2 mg kg^{-1}. Many studies have shown that zinc levels in tissues of wild ruminants (red and roe deer) did not differ significantly from those of farm animals (cows, sheep and goats) (Karpiński 1999). In addition, the analyses revealed that zinc concentrations were higher in muscle tissues compared to other tissues and organs. As Gasparik et al. (2012) indicated, Zn accumulated mainly in the liver. Significantly lower values were found in the kidney followed by the muscle.

The meat of wild boars from Podkarpacie was characterised by a high content of iron compared to the values published by other authors, e.g. Michalska, Żmudzki (1992) – from 22.9 to 48.6 mg kg^{-1}, Skobrak et al. (2010) – from 35.66 to 59.14 mg kg^{-1} and Skobrak et al. (2011) – from 39.83 to 55.66 mg kg^{-1}, Długaszek, Kopczyński (2013) – from 15.0 to 59.7 μg g^{-1}. Karpiński (1999) reported that the iron concentration in the meat of red and roe deer averaged 53.68 and 47.86 mg kg^{-1}, being similar to the values obtained by Skobrak et al. (2011) in pork. Iron is a borderline element between major and trace minerals. The high phosphate and phytate content of food impairs iron absorption, while a high-protein diet has the opposite effect (Karpiński 1999). The main components of wild boars' diet are cultivated crops, corn, potatoes, herbs, grasses, leaves and stems of plants, bark of trees and shrubs, blueberries and fungi (Długaszek, Kopczyński 2013).

Copper occurred in the smallest amount in the analysed meat of wild boars, but its concentration was still higher than the values reported by Michalska, Żmudzki (1992) – 1.92 mg kg^{-1} in autumn and 1.46 in spring and Kucharczak et al. (2003) – from 1.23 to 2.12 mg kg^{-1} and Falandysz (1994) – from 1.6 to 1.8 mg kg^{-1}. Karpiński (1999) showed that the highest amounts of copper were accumulated in the liver (16.24 mg kg^{-1} in roe deer and 13.34 mg kg^{-1} in red deer) and kidneys (7.47 mg kg^{-1} in roe deer and 11.95 in red deer). The lowest quantities of copper were found in skeletal muscles (2.82 mg kg^{-1} in red deer and 3.19 in roe deer). The analyses confirmed that ruminant animals are very sensitive to copper deficiency, and showed similar levels of this metal in the tissues of farm and game animals. The concentration of Cu in the wild boar from Slovakia was significantly lower in the muscle when compared to the liver and kidney (Gasparik et al. 2012).

Animals living freely in a natural ecosystem can also be a marker of environmental contamination. Heavy metals such as cadmium and lead accumulate in different organs of animals. A high content of these metals in animal tissues may pose a threat to consumers but can also serve to assess the extent of environmental pollution (Falandysz 1994, Szkoda, Żmudzki 2001, Kucharczak et al. 2003, Taggart et al. 2011, Gasparik et al. 2012).

The cadmium content of meat from the investigated wild boars was similar to the results obtained by Bilandžić et al. (2009) – from 0.01 to 0.23 mg kg^{-1}, Bilandžić et al. (2010) – from 0.005 to 0.062. Piskorová et al. (2003) showed

that the cadmium content of wild boar meat averaged 0.04 mg kg^{-1} and was similar to the values reported for foxes (*Vulpes vulpes*) – 0.03 mg kg^{-1}. In addition, the highest amounts of cadmium were found to accumulate in kidneys (0.56 mg kg^{-1} in wild boars and 0.25 in foxes). This is due to the fact that this organ is responsible for the excretion of toxins from the body (Drozd at al. 2001). As Rudy (2010) reported, the accumulation of lead and cadmium in muscles and in the liver increases together with the age of wild boars. However, most frequently statistically essential differences are found only between the group of the youngest and oldest animals. Moreover, in no single case was the maximum permissible level exceeded in meat for the content of 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).

Like cadmium, lead concentrations in the muscles of the animals we analysed were also within the limits stipulated in the ministry's regulation. These results were close to the values reported by Michalska, Żmudzki in 1992 (0.02 mg kg^{-1}). Piskorová et al. (2003) showed the lead content of wild boar meat to average 0.17 mg kg^{-1}, which was similar to the values reported for foxes (0.14 mg kg^{-1}). Analyses of different organs showed that the highest amounts of lead were accumulated in kidneys (0.39 in wild boars and 0.38 mg kg^{-1} in foxes). Different results were obtained by Szkoda, Żmudzki (2001). They showed the average lead content of wild boar meat to range from 0.121 to 0.437 mg kg^{-1}, exceeding the maximum admissible levels in over 20% of the samples. This may be due to lead intoxication from gunshot wounds (Dobrowolska, Melosik 2008). For this reason, muscle tissue should not be regarded as a reliable indicator of the degree of ecosystem contamination by this element. Michalska, Żmudzki (1992) demonstrated that the average concentration of lead in the organs of roe deer was higher than in cattle from the same region, which is the evidence that wild game are more exposed to a direct impact of environmental contamination compared to farm animals. The significantly highest accumulation of Cd in the kidney of wild boar (*Sus scrofa* L.) of western Slovakia, followed by the liver and muscles, was demonstrated by Gasparik et al. (2012).

The coefficients of correlation were analysed to estimate an antagonistic or synergistic interaction between the elements determined in the meat from wild boars (Table 2).

Our analysis of the correlations between mineral elements in wild boar meat showed only one positive and statistically significant correlation, namely between the average content of K and Mg. The interaction of Fe with the other elements, including heavy metals, has an effect on its absorption and metabolism. Cd and Pb are particularly antagonistic to Fe. The interactions between Pb and the other elements contribute significantly to disturbances in the metabolism of other elements essential for health. The antagonistic effect of lead on other metals is associated with their affinity for

Table 2

The values of the Peasron's coefficient correlation for choosen metals determined in the meat of wild boar (*Sus Scrofa* L.) from the Province of Podkarpacie

K	0.281281						
Mg	0.270377	0.797820*					
Zn	0.254769	0.219939	0.137997				
Fe	-0.174935	-0.094166	-0.413354	0.085431			
Cu	-0.326311	0.603048	0.603315	0.032251	0.206648		
Cd	-0.444169	-0.081666	0.093392	-0.120017	-0.135072	0.158071	
Pb	-0.168069	-0.368671	-0.458012	0.624080	0.201919	-0.288447	-0.175642
	Na	K	Mg	Zn	Fe	Cu	Cd

Statistically significant values are marked with asterisks at $p \leq 0.05$.

binding with proteins. An increase in the lead content accelerates the excretion of Fe and Cu. Pb inhibits the formation of ceruloplasmin, which is involved in the Fe and Cu metabolism. An increase in the dietary level of Cu decreases Pb sorption. According to Gasparik et al. (2012), the correlation between Zn and Cu in the muscle of wild boar of western Slovakia was positive ($r = 0.59$). The antagonism between Cd and Fe is linked to the Cd-Cu antagonism and reduces Fe absorption in the body, whereas the Cd-Ca interaction increases Ca excretion in response to Cd.

CONCLUSIONS

The *longissimus dorsi* muscles of both male and female wild boars had a similar content of minerals, as evidenced by the lack of significant differences for most elements except copper, for which a statistically significant difference was found ($p \leq 0.01$). Based on the content of selected heavy metals (cadmium and lead) in the muscles of the investigated animals, it can be concluded that the meat was suitable for consumption and the animals did not live in an environment with a high concentration of heavy metals.

Comparison of our results with those of other authors shows that wild boar meat has a higher content of the analysed elements compared to pig meat (Falandysz 1993, Greenfield et al. 2009, Tomović et al. 2011, Lopez-Alonso et al. 2012).

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