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Dependences between the age and the level of bioaccumulation of heavy metals in tissues and the chemical composition of wild boars' meat

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Abstract

This study was conducted to determine the level of accumulation of selected heavy metals (Pb, Cd, Hg, As) in tissues of wild boars. The tested animals were divided into 3 age groups, which allowed the analysis of statistical-mathematical dependences between the age of animals and contamination of their tissues. The samples for determining the content of heavy metals were taken from the longissimus muscle of back, and samples of liver from the tail lobe. It has been stated that accumulation of lead and cadmium in muscles and in liver increases together with the age of wild boars. However, most frequently the statistically essential differences were 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 contents of lead, cadmium or mercury. In the samples of tissues of wild boars arsenic was not detected above 0.001 mg/kg. In the group of animals above 3 years in the case of two samples the maximum permissible level of cadmium in liver (0.5 mg/kg) was exceeded.

Keywords: Meat of wild boars; heavy metals; coefficients of correlation

Introduction

Currently among consumers there is increased interest in meat from animals kept in conditions as close as possible to the natural ones. Such a requirement is undoubtedly fulfilled by game characterized by high nutritional value and special sensory properties, desired by consumers (Daszkiewicz 2007; Soriano et al. 2006; Vergara et al. 2003).

However, animals living in the natural ecosystem often show higher levels of contamination by xenobiotics compared to farm animals and can constitute a bigger hygienic-toxicological threat. Integration of these animals with the environment for the whole (relatively long) period of life means these species can be used as an excellent indicator of the level of contamination of their natural habitat.

In the research reported here the content of such elements as lead, cadmium, mercury and arsenic in tissues of wild boars was determined because they constitute a real danger for health due to high toxicity. These metals can produce neuro-toxic, carcinogenic effects, they disturb functioning of cardiovascular system, osseous system, and organism's management of minerals. Moreover, ions of these elements do not undergo biodegradation, thus they circulate in the environment and accumulate in tissues of living organisms.

Among the tests on wild mammals, numerous publications concern the load of their tissues and organs with heavy metals indicating the practical value of these tests for the assessment of quality of the environment. Some animals are good bio-indicators such as the hare (*Lepus europaeus*) (Baikov et al. 1994; Bukovjan et al. 1995; Milanov 1995; Paukert and Obrusnik 1986), deer, elk, reindeer (Frøslie et al. 1984; Niemi et al. 1993; Venäläinen et al. 1996) and wild boar (Falandysz 1994; Falandysz and Lorenc-Biała 1988; Krupa and Szmulik 2000; Kryński et al. 1996; Kryński and Wrzesień 1994; Michalska and Żmudzki 1992; Monkiewicz and Jaczewski 1990; Racz and Vandewaterl 1982).

Many authors (Gufler et al. 1997; Holm 1993; Kottferova and Korenekova 1998; Pokorny and Ribaric-Lasnik 2000; Szkoda and Żmudzki 2001) noted higher concentrations of cadmium and lead in tissues of game (roe deer, wild boar) than the levels of these elements found in other tests conducted on farm animals such as: pigs (Jorhem et al. 1991; Larsen et al. 2002; Niemi et al. 1991), cattle (López et al. 2000; Tahvonen and Kumpulainen 1994) or sheep

(Niedziółka et al. 2004; Rudy 2009). However, in the case of the contents of these metals in tissues of horses, many researchers (Baldini et al. 2000; Rudy et al. 2007; Salisbury et al. 1991; Weyermann and Lückner 1998) found that the maximum permissible levels for these toxicants were exceeded, especially such cases occurred in the material obtained from older animals.

The measured contents of total mercury and arsenic in food and feedstuff indicate that these elements usually occur in low concentrations. Most frequently there are found as contaminants in seafood, however, arsenic is also found in tissues of other animals (Jorhem et al. 1991; Krupa et al. 1995). In the case of mercury it is still the subject of interest of many researchers (Dickman et al. 1999; Innis et al. 2006; Morita et al. 1998; Naqvi et al. 2003; Nguyen et al. 2005; Olivero et al. 1997; Storelli et al. 2003) and both mercury as well as arsenic are taken into consideration in every program of monitoring tests.

In this connection the purpose of the work reported here was to determine the level of accumulation of selected heavy metals (Pb, Cd, Hg, As) in tissues of wild boars. The animals were divided into 3 age groups, which allowed the analysis of statistical-mathematical dependences between the age of animals and contamination of their tissues. Moreover, the chemical composition of meat in particular age groups of wild boars was also determined to look for dependences between the accumulation of heavy metals and the contents of water, protein, fat and ash in meat. It also allowed an understanding of nutritional-health dependences between the age of animals and basic chemical components of meat which in great measure shapes its quality and nutritional value. In addition, the contents of the above-mentioned toxicants in tissues presented in the work allowed stating the degree of contamination of the habitat of wild boars analyzed in the years (tests in the years 2002 – 2006).

Materials and methods

The research was carried out between 2002 and 2006 on wild boars in south-eastern Poland (Podkarpackie and Lubelskie provinces), an area with small-scale mixed farming and practically with no industry. As 95% of the soils have very low heavy metal concentrations, the region has excellent potential for the production of high quality food with superior health

and nutritional value (Sucha and Zawada 1994). Concentration of heavy metals both in soil and drinking water are within standard regulatory limits.

Wild boars were shot by hunters from the nearby hunters' associations of South-East Poland. The size in each age group and in every year of tests was by 20 heads. The age of wild boars was determined on the basis of external appearance (colour, height, length of fang wear). On the basis of the results of earlier author's tests it was found that wild boars at the age of up to 1 year have lower immunity in preventing accumulation of toxic elements in their tissues. And the biggest part of wild boars shot in Poland are animals at the age between 1 and 3 years, and in the second place in this respect are wild boars between 3 and six years of age. In this connection in this paper there were analysed tissues of wild boars from these age intervals. The test material constituted so wild boars which were divided into 3 age groups:

Group I – to 1 year,

Group II – from 1 to 3 years,

Group III – over 3 years to 6 years.

The samples for tests were meat and liver. For the purpose of determining the chemical composition of meat a sample was taken from a part of longissimus muscle of back (*m. longissimus dorsi*) at the height of the last thoracic vertebrae. The content of water was determined in accordance with the standard PN-ISO 1442:2000. Protein was determined with Kjeldahl's method, with the content of nitrogen converted into protein according to PN-75/A-04018. The content of fat was determined with Soxhlet's method in accordance with recommendations of PN-ISO 1444:2000, and the total ash was determined in accordance with the guidelines contained in PN-ISO 936:2000.

For determination of heavy metal levels, i.e. arsenic, cadmium, lead and mercury, samples were taken (at least at 100 g from the same part of each tissue) also from a section of the longissimus back muscle (*m. longissimus dorsi*) at the level of the last thoracic vertebra; samples of liver were taken from the tail lobe. Sampled material was lyophilized (FreeZone6L; Labconco, Kansas, City, MO, USA), homogenized and then mineralized using the pressure-microwave method (MARS XPRESS, CEM Corporation, Matthews, NC, USA) in nitric acid/hydrogen peroxide mixture (6:1, v/v), according to PN-EN 13805:2003.

This procedure was simultaneously carried out for reagent blanks. The digested solutions were diluted so that the measured concentrations of a given element were, if possible, in the centre of the operating range. Arsenic was determined by hydride generation atomic absorption spectrometry (HGAAS) according to PN-EN 14627:2005. Pb and Cd were determined by graphite furnace atomic absorption spectrometry (GFAAS) (SpectrAA 880Z; Varian, Walnut Creek, CA, USA) according to PN-EN 14084:2004. Hg was determined by cold vapour atomic absorption spectrometry according to PN-EN 13806:2003. The levels of heavy metals in tissues were expressed in mg/kg of fresh mass, taking into account all quantitative processes during material preparation and reagent blanks. The hydride generation conditions for arsenic and for mercury determination:

As – wavelength 193.7 nm, slit 0.7 nm, cell temperature 900°C, reducing agent 0.2% w/v NaBH₄, sample injection volume 500 µL;

Hg – wavelength 253.7 nm, slit 0.5 nm, cell temperature 300°C, reducing agent 0.2% w/v NaBH₄, carrier 3% v/v HCl, sample injection volume 500 µL.

As a modifier of matrix at determining Cd and Pb there was applied: 1% NH₄H₂PO₄ + 0.3% Mg(NO₃)₂.

The determinations of selected elements in the analysed period were made by the same analyst, in the same laboratory and under the same conditions. Moreover, the applied analytical procedures were regularly verified in intra- and inter-laboratory tests by the analysis of control samples enriched with various concentrations of tested compounds and the analysis of certified reference materials. The laboratory also participated regularly in domestic and international tests of expertise.

In all cases, the blanks were treated in the same way as samples. A strict analytical quality control program was employed during the study, the results of which are presented in Table 1. The limits of detection, expressed as concentration in the tissue, was based on the mean sample weight for that tissue type. Quality control of analytical measurements was performed using blank samples and the following certified reference materials: BCR-185R bovine liver from the Institute for Reference Materials and Measurements for the determination of lead, cadmium and arsenic, and NIST-RM 8414 bovine muscle powder from the National Institute of Standards and Technology for the determination of mercury.

The results were subjected to statistical-mathematical analysis which included:

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1. Calculation of basic statistical measures of position (arithmetic mean) and scatter (standard deviation). These parameters were calculated in order to characterize the determined quantities of water, protein, fat and ash in meat. And for the purpose of characterising the determined quantities of cadmium, lead, mercury and arsenic in tissues of the assessed animals there was calculated the arithmetic mean and the minimum and maximum values were given.
2. One-factor variance analysis which was checked by Tukey's confidence intervals, at to levels of significance $P \leq 0.01$ and $P \leq 0.05$. The null hypothesis in variance analysis was verified by the test formulated by Fisher Snedecor (test F).
3. Calculation of the value of coefficients of simple correlation for the purpose of determining interdependences between the content of tested metals in meat and liver of wild boars and dependences between the chemical composition of meat and the determined toxicants. There were also calculated coefficients of correlation to determine the correlation between the examined features and age of animals. Coefficients of correlation were calculated at the significance level $P \leq 0.05$.

Calculations were made basing on the program STATISTICA ver. 6.0.

Results and discussion

The contents of the basic components in meat of wild boars (protein 17-24%, fat 1.5-3.2%, water 71-74%, ash 1%), as with other animals, depends mainly on the age and place of taking the sample (Korzeniowski and Żmijewski 2001).

In the author's tests (Table 2) there were stated increase with age of the content of protein, fat and ash and decrease of the contents of water. Particularly high difference (as much as 186%) occurs in the contents of fat between the animals up to 1 year and animals above 3 years. Between these groups the difference in the contents of protein is 2 percentage units and in the contents of water 3.6 percentage units.

One of the methods of control of the quality of the environment and health and correct development of vertebrates, including mammals, are the eco-toxicological tests. One of essential elements of these tests is the analysis of tissues and organs of animals for the purpose of determining the amount of occurrence of heavy metals in them. Any quantitative changes in the environment are reflected in tissues of animals, but the sensitivity of these

“living sensors” is very variable, even within the same species. Within hundreds of millions of years the living organisms created excellent mechanisms registering the changes in physical and chemical parameters of atmosphere, water and soil. This ability enables reacting even for the most subtle changes in the surrounding environment, which cannot be detected even by the most sensitive measuring devices.

The contents of heavy metals in tissues of wild boars in the years 2002-2006 is presented in Table 3. From these data it appears that the contents of cadmium in meat was varied in individual years and fluctuated within the limits from 0.047 mg/kg in the year 2003 to 0.077 mg/kg in the year 2004. It was similar in the case of concentration of cadmium in meat whose amount fluctuated within the range from 0.012 mg/kg in the year 2005 to 0.015 mg/kg in the year 2002. Also the contents of mercury in this tissue fluctuated within the limits from 0.001 mg/kg in the year 2006 to 0.008 mg/kg in the year 2004. However, for the contents of these metals in muscular tissue there were not stated statistically significant differences between the years. In the analyzed samples of meat and liver of wild boars the presence of arsenic was not detected. But the presence of Pb in liver (0.145 mg/kg) in the years 2002-2003 increased by approximately 11% in the years 2004-2005 and by 31% in the year 2006 (statistically significant differences $P \leq 0.01$ occurred between the years 2003 and 2006). In turn, the concentration of cadmium in liver of wild boars was the lowest in the years 2002 and 2006 (0.290 mg/kg) and increased in the years 2003 - 2005 by: 15%; 33% and 44% respectively. However, statistically significant differences ($P \leq 0.01$) occurred only between the year 2002 and the years 2004 and 2005. It should be also emphasized that in the year 2005 for one sample there was exceeded the permissible amount of this element in liver (0.5 mg/kg). Also in liver of wild boars there was found the presence of mercury whose contents fluctuated within the range from 0.001 mg/kg in the year 2002 to 0.004 mg/kg in the year 2005.

In the years 1996-1997 Krupa and Szmulik (2000) in tissues of wild boars from South-East Poland showed much higher level Pb, Cd, Hg and As both in muscles and in liver – respectively: 0.104 mg/kg; 0.035 mg/kg; 0.018 mg/kg and 0.0041 mg/kg in muscles and 0.196 mg/kg; 0.562 mg/kg; 0.057 mg/kg and 0.0082 mg/kg in liver than in the author’s tests (Table 3). Also the tests conducted in the eighties by other authors (Falandysz and Caboń 1990; Falandysz and Lorenc-Biała 1988) prove higher concentration of lead in muscles (0.14 – 0.16 mg/kg) and in liver (0.25 – 0.31 mg/kg) of wild boars than in this work. Still higher

concentration of lead in muscle and liver of wild boars was showed by Kryński et al. (1996) respectively: 0.24 mg/kg and 2.28 mg/kg. Falandysz and Lorenc-Biała (1988) towards the end of the eighties showed the contents of cadmium in muscles of wild boars (from North Poland) at the level of 0.01 mg/kg and in liver 0.11 mg/kg. In turn, Kryński et al. (1996) stated a few times higher concentration of this element both in meat (0.13 mg/kg) and in liver (0.24 mg/kg) of wild boars from the area of South-West Poland. Similar contents of cadmium in liver was stated in the author's tests (Table 3) in the year 2002. In turn, in the tests of Szkoda (2006) it was shown that a serious hygienic-toxicological problem is the contamination by lead of meat obtained from game. High concentrations of Pb in samples of muscles, reaching several tens mg/kg, at low contents of this element in kidneys and liver prove contamination of muscles by lead from bullets used for shooting. The number of individual samples of muscles of game, in which there was exceeded the current limit, i.e. 0.10 mg/kg, reached the level of 39%. Such a considerable percentage of samples with high concentration of lead is a special threat for human health even at low consumption of meat of game. Such a condition indicates the need of permanent inspection of venison in order to protect the consumer's health and commencement of efficient actions eliminating this problem.

Krupa and Szmulik (2000) in their tests obtained quite considerable degree of contamination by cadmium and mercury of internal organs of roe deer and wild boars. Therefore, the offal of these animals should be eliminated from foodstuff use. Only the level of contamination by arsenic and lead of tissues of roe deer and wild boars did not bring sanitary-toxicological reservations.

In the tests conducted in the area of South Tyrol in the hunting season in 1995 Gufler et al. (1997) stated definitely higher average contents of cadmium in kidneys of roe deer (1.333 mg/kg) in relation to the levels occurring in liver of these animals (0.120 mg/kg). In turn, in the tests conducted in the industrial areas of Slovenia the concentration of cadmium in liver of roe deer was at the level of 3.920 mg/kg, and in kidneys it was above 22 mg Cd/kg (Pokorny and Ribaric-Lasnik 2000).

The data concerning the contents of heavy metals in meat and liver of wild boars of different age are in Table 4. From these data it appears that the contents of lead in muscular tissue was varied depending on the age (very high correlation - $r = 0.81$). But the lowest contents of lead in meat 0.042 mg/kg was found in the youngest specimens. The amount of this element

increased in subsequent age groups - by 26% and 95% respectively. In the case of the contents of cadmium in meat the amount of this metal also increased from the level of 0.008 mg/kg in group I by 75% in group II and by 112% in group III. Statistically significant differences ($P \leq 0.01$) for the contents of both metals in meat were confirmed only between the groups I and III. Also the contents of mercury in meat as well as in liver of wild boars increased together with their age. However, both for the contents of this element in liver as well as in meat there were not confirmed statistically significant differences. Also in no single case was exceeded the maximum permissible level in meat, both for the contents of lead, cadmium as well as mercury. In the tested samples of tissues there were also not stated the presence of arsenic above 0.001 mg/kg. High diversity in the contents of lead (0.01 – 0.078 mg/kg) and cadmium (0.01 – 0.10 mg/kg) in meat of wild boars coming from Pomorze (*maritime region*) was obtained in his tests by Falandysz (1994). The same author in other tests (Falandysz and Caboń 1990; Falandysz and Lorenc-Biała 1988) also obtained higher concentration of lead both in liver and meat of wild boars.

In the case of contents of lead and cadmium in liver of wild boars (Table 4) the amounts of these metals were considerably dependent on the age of these animals (high correlation – $r = 0.76$ and 0.83 respectively). The contents of Pb in the liver was lowest in group I – 0.017 mg/kg and increased in successive age groups by 46% and 92% respectively (statistically significant differences $P \leq 0.01$ were confirmed between the groups I and III). Similarly, the lowest contents of Cd in liver 0.251 mg/kg was obtained by the youngest specimens. The contents of this metal increased in successive age groups by 46% and 90% respectively (statistically significant differences $P \leq 0.01$). Moreover, in the group of animals above 3 years in the case of two samples the maximum permissible level of this metal in liver (0.5 mg/kg) was exceeded, and the average concentration of cadmium in this organ of wild boars from group III approached this limit and was 0.478 mg/kg. Falandysz (1994) in his tests also observed high diversity as to the amount of Pb (0.02 – 1.30 mg/kg) and Cd (0.05 – 0.68 mg/kg) in liver of wild boars. However, Krupa and Szmulik (2000) showed much higher level of Pb, Cd, Hg and As in muscles and in liver of wild boars than the author of this work for all age groups of these animals (Table 4). Only in the case of concentration of lead in liver the specimens from group III obtained higher values. In turn, Holm (1993) in samples of livers collected from roe deer shot in the area of East Saxony noted the following amounts of cadmium (0.390 mg/kg) and lead (0.040 mg/kg). On the other hand, Kottferova and Korenekova (1998) in organs of roe deer and wild boars shot in the area of Slovakia stated the

contents of lead at the level respectively: 0.120 mg/kg and 0.250 mg/kg in liver and 0.250 mg/kg and 0.670 mg/kg in kidneys of these species of animals.

In Table 5 there are presented the coefficients of simple correlation between the contents of heavy metals in tissues of boars. From these data it appears that together with the increase of the amount of lead in liver there increased the amount of lead in meat ($r = 0.88$) and of cadmium in meat ($r = 0.82$), and also that together with the increase of the content of cadmium in liver there increased the content of the following metals: Pb in meat ($r = 0.78$), Cd in meat ($r = 0.81$) and Pb in liver ($r = 0.75$). Also together with the increase of the concentration of mercury in liver there increased the concentration of this element in meat ($r = 0.62$) and the concentration of lead in liver ($r = 0.60$). Also the increase of the amount of cadmium in meat caused the increase of lead in this tissue ($r = 0.83$). In the majority of cases these were statistically significant differences, which means that the level of accumulation of lead and cadmium in liver is a good indicator of contamination of muscular tissue by these metals in remaining muscles obtained from carcasses of wild boars.

Coefficients of simple correlation between the chemical composition of meat and the contents of heavy metals in meat and liver of wild boars are presented in Table 6. From these data it appears that the majority of coefficients of correlation were positive. The exception were the interdependences between the contents of water in meat and the concentration of lead, cadmium and mercury in meat. For these dependences there were noted negative coefficients (statistically insignificant). However, positive and significant correlations occurred between the contents of chemical fat in meat and the contents of lead in meat ($r = 0.53$) and in liver ($r = 0.62$) of wild boars, and also between the amount of ash in meat and the concentration of lead in liver ($r = 0.52$) of these animals.

Sikora (1993) carried out analysis of coefficients of correlation between the contents of basic chemical components of meat and the contents of elements (Cd, Pb, Fe, Zn, Cu, Mn, Mg, Ca) in meat and liver of rabbits. From these tests it appears that between the contents of fat and the contents of analyzed elements, both in meat and liver, there were no significant coefficients of correlation. However, the analysis of interdependences with the contents of protein conducted by this author, in the analogous arrangement, confirmed significant coefficients of correlation (although not high). In the case of meat for Zn and Mg, and in the case of liver for Zn, Cu, Mn and Mg. This observation may confirm the assumption of

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3 accumulation of contaminants in the protein system and not in fat of animals. The data
4 presented in this work (Table 6) allows us to conclude that with increasing amounts of fat and
5 ash in meat of wild boars that there is an increase in the contents of lead and cadmium, both in
6 meat and in liver of these animals. In the case of the contents of protein in meat such
7 dependences were not found.
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12 13 14 **Conclusions**

15 The analysis carried out in the previous chapter allows stating that accumulation of lead and
16 cadmium in muscles and in liver increased together with the age of wild boars. However,
17 most frequently the statistically essential differences were found only between the group of
18 the youngest and oldest animals. Moreover in no single case was exceeded the maximum
19 permissible level in meat, both for the contents of lead, cadmium as well as mercury. In the
20 tested samples of tissues of wild boars there were also not stated the presence of arsenic above
21 0.001 mg/kg. In the group of animals above 3 years in the case of two samples the maximum
22 permissible level of cadmium in liver (0.5 mg/kg) was exceeded. There was found very high
23 positive correlative dependence between the contents of lead and cadmium in liver and
24 concentration of these elements in muscles. Which means that the level of accumulation of
25 lead and cadmium in liver is a good indicator of contamination of muscular tissue with these
26 metals in remaining muscles obtained from carcasses of wild boars. The level of tested
27 contaminations in tissues of wild boars in the analysed period (years 2002 - 2006) was most
28 often diversified and it cannot be explicitly stated that in this period there increased
29 contamination of natural habitat of these animals.
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Table 1. Analytical quality control program used in the determination of cadmium (Cd), lead (Pb), mercury (Hg) and arsenic (As) in wild boars samples

Quality characteristics	Pb	Cd	As	Hg
Detection limit in samples (mg/kg)				
Muscle	0.002	0.001	0.001	0.0001
Liver	0.004	0.002	0.001	0.0001
	Certified Reference Material BCR – 185R (Bovine Liver)			NIST - Reference Material 8414 (Bovine Muscle Powder)
Measured mean $\pm$ SD (mg/kg)	0.165 $\pm$ 0.010	0.515 $\pm$ 0.021	0.029 $\pm$ 0.003	0.0045 $\pm$ 0.0005
Certified mean $\pm$ SD (mg/kg)	0.172 $\pm$ 0.009	0.544 $\pm$ 0.017	0.033 $\pm$ 0.002	0.005 $\pm$ 0.003
Recovery (%)	95.9	94.7	87.9	90.0
Relative standard deviation (%)	6	4	10	11

Table 2. Chemical composition of meat of wild boars of different age (%)

Composition of muscle tissue	Groups						r	$\bar{x}$
	I		II		III			
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S		
Water	76.90	4.50	75.10	5.10	73.30	4.10	-0.84*	75.10
Protein	21.20	1.80	21.90	1.20	23.20	1.60	0.75*	22.10
Fat	0.70	0.30	1.40	0.20	2.00	0.50	0.68*	1.13
Ash	1.10	0.20	1.40	0.40	1.40	0.30	0.49	1.30

* - values significant at $P \leq 0.05$

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Table 3. The content of heavy metals in meat and liver of wild boars in the years 2002-2006 (mg/kg)

Specification	2002			2003			2004			2005			2006			The significance of differences
	$\bar{X}$	$X_{\min}$	$X_{\max}$	$\bar{X}$	$X_{\min}$	$X_{\max}$	$\bar{X}$	$X_{\min}$	$X_{\max}$	$\bar{X}$	$X_{\min}$	$X_{\max}$	$\bar{X}$	$X_{\min}$	$X_{\max}$	
Meat:																
Pb	0.060	0.039	0.072	0.047	0.041	0.071	0.077	0.047	0.093	0.057	0.047	0.087	0.062	0.045	0.083	
Cd	0.015	0.009	0.020	0.013	0.008	0.019	0.014	0.006	0.019	0.012	0.010	0.018	0.014	0.008	0.020	
Hg	0.005	0.001	0.008	0.002	0.001	0.006	0.008	0.002	0.009	0.007	0.003	0.010	0.001	0.001	0.001	
As	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Liver:																
Pb	0.145	0.103	0.187	0.146	0.125	0.197	0.161	0.116	0.264	0.162	0.122	0.234	0.190	0.117	0.430	2003<2006*
Cd	0.290	0.232	0.338	0.333	0.275	0.376	0.387	0.301	0.493	0.417	0.391	0.565	0.292	0.089	0.442	2002<2004,2005*
Hg	0.001	0.001	0.001	0.003	0.001	0.005	0.001	0.001	0.001	0.004	0.001	0.006	0.002	0.001	0.002	
As	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	

* - differences significant at $P \leq 0.01$.

Table 4. The content of heavy metals in meat and liver of wild boars of different age (mg/kg)

Specification	Groups									r	The significance of differences
	I			II			III				
	$\bar{X}$	$x_{\min}$	$x_{\max}$	$\bar{X}$	$x_{\min}$	$x_{\max}$	$\bar{X}$	$x_{\min}$	$x_{\max}$		
Meat:											
Pb	0.042	0.039	0.045	0.053	0.045	0.067	0.082	0.047	0.087	0.81*	I<III*
Cd	0.008	0.006	0.011	0.014	0.011	0.018	0.017	0.015	0.018	0.43	I<III*
Hg	0.003	0.001	0.005	0.006	0.003	0.008	0.008	0.005	0.010	0.38	
As	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
Liver:											
Pb	0.117	0.103	0.130	0.171	0.137	0.210	0.225	0.182	0.264	0.76*	I<III*
Cd	0.251	0.232	0.271	0.367	0.272	0.395	0.478	0.378	0.565	0.83*	I<II,III*
Hg	0.001	0.001	0.001	0.004	0.001	0.006	0.005	0.002	0.006	0.48	
As	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-

* - differences significant at $P \leq 0.01$.

Table 5. Coefficients of simple correlation between the content of heavy metals in meat and liver of wild boars

Pb meat	-							
Cd meat	0.83*	-						
Hg meat	0.53	0.45	-					
As meat	-	-	-	-				
Pb liver	0.88*	0.82*	0.41	-	-			
Cd liver	0.78*	0.81*	0.48	-	0.75*	-		
Hg liver	0.45	0.53	0.62*	-	0.60*	0.43	-	
As liver	-	-	-	-	-	-	-	-
	Pb meat	Cd meat	Hg meat	As meat	Pb liver	Cd liver	Hg liver	As liver

* - coefficients significant at $P \leq 0.05$

Table 6. The coefficients of simple correlation between the chemical composition of meat and the contents of heavy metals in meat and liver of wild boars

Specification	Pb meat	Cd meat	Hg meat	As meat	Pb liver	Cd liver	Hg liver	As liver
Water	-0.15	-0.21	-0.02	-	0.20	0.17	0.03	-
Protein	0.29	0.21	0.07	-	0.19	0.30	0.04	-
Fat	0.53*	0.42	0.05	-	0.62*	0.49	0.05	-
Ash	0.39	0.31	0.09	-	0.52*	0.45	0.09	-

* - coefficients significant at $P \leq 0.05$