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Nutritional composition and heavy metal content in breast and thigh muscles of wild and intensively reared common pheasants *(Phasianus colchicus)*

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Abstract

Introduction: Differing conditions in captive breeding and in the wild have impact on the mineral profile of the pheasant carcass and its heavy metal contents. This may be an indicator of environmental contamination. The study evaluated the nutritional composition and selected macro- and trace element contents (heavy metals in particular) in usable sections of pheasant breast and thigh muscles originating from captive breeding and wild birds. **Material and Methods:** The tests were performed on the breast and thigh muscles of 20 wild and 20 farm bred birds from around Lublin, Poland, with equal sex representation. The nutrient and lead, cadmium, chromium, and nickel contents were determined using inductively-coupled plasma atomic emission spectroscopy. **Results:** The farmed pheasants had a higher proportion of breast muscle. The thigh muscles of all birds had a higher fat content than the breast muscles (5.1 g *vs*. 3.4 g per kg of natural weight). The macroelement level depended on the muscle type and bird origin. The trace element content also did and gender dependence was also evident. The wild birds contained more cadmium in the breast muscles and lead in both muscles than the farm-raised ones. **Conclusion:** The high quality and usefulness of wild and farmed pheasant meat is confirmed. It has advantageous macro- and trace element contents and permissible heavy metal contents except for lead in wild birds. The heavy metal level can be a bioindicator of their environmental occurrence. In wild birds, the lead level may also reflect birdshot remnants.

Keywords: pheasants, chemical composition of muscles, heavy metals, environmental contamination.

Introduction

Wild animals are affected by the environment, and thus, can be excellent bioindicators for assessing its richness in nutrients and the possibility of its contamination. These animals are in a much closer relationship with environmental geochemical systems than those kept in containment. They are also more exposed to adverse factors, including low doses of heavy metals in the environment which they inhabit. Therefore, in animals living in natural ecosystems, the level of some heavy metals is often higher than in farmed animals (22, 30, 32, 37). In game animals, secondary lead contamination may also occur through bullets and the accidental consumption of lead shot in the environment (9, 13, 29). The accumulation of heavy metals, including toxic ones, and the deficiency of some bioelements may have a significant impact on animal health including game animals and the quality of the obtained carcasses. The content of heavy metals in food also significantly affects the reproductive processes of some animals in the trophic chain. These types of threats mainly affect mammals, birds of prey, and the scavengers that feed on carrion when animals injured during hunting die and are not found by hunters (5, 7, 9, 33).

In recent years, there has been an increase in interest in food of natural origin, thus increasing consumer attention is directed to game. Game products are more nutritious and recommendable for dietary reasons, one of which is their content of mineral elements. Previous studies on the content of micro- and

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macroelements in the tissues of wild animals have focused mainly on game as large as deer and wild boar (22, 30, 32). Although consumption of meat from wild game birds does not match the scale of the consumption of venison, consumer interest is expressed increasingly towards the meat of pheasants, among other varieties. Research on the chemical composition of the meat of partridges and pheasants principally, but also that of other small animals inhabiting mainly agrarian and segetal environments, has been and is still being conducted (12, 17, 18, 31). The meat of these birds is characterised by its high nutritional value, resulting from a significant protein content and low fat content (36, 40). The majority of previous studies concerned captive-bred animals (4, 17, 18, 24, 27, 38). Research by some authors indicates significant differences in the slaughter performance of wild and farmed birds. These differences also apply to the amino acid composition and fatty acid profile of individual muscle groups (31, 36).

Despite its high nutritional and dietary value, pheasant meat remains a niche product (2, 3, 18). This status is mainly influenced by the difficulty of obtaining it, and in the case of wild pheasants, the fairly high price of the carcasses and the seasonality of access to them resulting from hunting season restrictions (11, 28, 34). Nevertheless, due to the fact that full containment farms raise this species both for release into hunting grounds and for the table, the availability of carcasses is definitely higher than that of other species of wild birds (14). Therefore, it is interesting to compare the nutritional value, and especially the mineral composition of pheasant carcasses obtained from natural habitats and from farm bred where the composition of feed and living conditions are subject to specific control.

The aim of the study was to evaluate the nutritional composition and the content of selected macro- and trace elements in the usable pieces of pheasant breast and thigh muscles from farm bred and wild birds, with particular reference to heavy metals.

Material and Methods

Animals. The pheasant muscles used for the analysis were obtained from wild birds shot in accordance with hunting regulations, and from farm bred birds. The wild pheasants came from hunting areas in the Lublin Upland, while the captive bred animals came from farms in the same area. In the case of the farmed pheasants, the birds were aged 38 weeks. In the wild birds, the age was assessed on the basis of characteristic features, *i.e*. the colour of the watercourses, beak shape, the bursa of Fabricius, and the shape and development of the spurs in the males (39). Only birds in the first year of life were used for analysis, *i.e.* individuals which hatched in spring and were shot at the turn of November and December. The farm birds were kept in an aviary system located far from public roads, and anthropogenic factors did not affect the raising of the birds. They were fed complete mixtures with a varied content of nutrients adapted to their age (Table 1).

Table 1. Ingredients (g kg^{-1}) and nutritive value of reared pheasant diet

Components	Reared (0–4 weeks)	Reared (5–8 weeks)	Fattening (9–38 weeks)
Corn	232.1	272.3	291.6
Wheat	100.0	100.0	160.0
Soybean meal	280.0	280.0	250.0
Garden pea	50.0	50.0	50.0
Fish meal	80.0	20.0	-
Linseed	40.0	40.0	40.0
Sunflower meal	80.0	80.0	80.0
Soya oil	50.0	50.0	-
Sorghum	10.0	30.0	50.0
Dicalcium phosphate	16.0	16.0	17.0
Calcium carbonate	55.0	55.0	55.0
Salt	3.0	3.0	3.0
Mineral-vitamin premix	2.5	2.5	2.5
DL-methionine	0.5	0.4	0.3
L-lysine chloride	0.9	0.8	0.6
Analysed value:			
Dry matter	896.9	895.4	894.8
Crude protein	278.7	230.7	189.2
Crude ash	70.,1	69.,2	69.,3
Calcium	26.1	26.3	26.4
Total phosphorus	7.9	7.8	7.7
Iron, mg kg^{-1}	179.2	176.3	174.5
Zinc, mg kg^{-1}	132.4	129.5	125.4
Copper, mg kg^{-1}	22.9	22.8	22.7
AMEn, MJ kg^{-1}*	12.05	12.06	10.57

Mineral-vitamin premix in farm-bred group contained in 1 kg diet: Mn – 60 mg; I – 1 mg; Fe – 54 mg; Zn –100 mg; Cu – 11 mg; Se – 0.2 mg; vit. A – 10,000 IU; vit. D_3– 2,500 IU; vit. E – 50 mg; vit. K_3 – 2 mg; vit. B_1– 1.5 mg; vit. B_2– 4.5 mg; vit. B_6– 3 mg; vit. B_{12}– 0.015 mg; biotin – 0.1 mg; folic acid – 0.8 mg; nicotinic acid – 20 mg; pantothenic acid – 12 mg; choline – 300 mg

*AMEn – apparent metabolisable energy at zero nitrogen balance was calculated with Fisher and McNab's (8) equations

The composition of the wild birds' diet was not strictly defined, as it is mainly dependent on the conditions in the habitat in which the birds live, and thus its specifics vary through particular periods of the growing season.

Preparation of tests. Samples were taken from 10 wild males and 10 wild females and from the same number of farmed birds. The farmed birds were stunned and decapitated. After 12 h of cooling, the wild and captive-bred birds' carcasses were dissected to collect the material of the breast muscles (*Musculus pectoralis*) and thigh muscles (*Musculus femoris* and *Musculus gastrocnemius*). Dissection was carried out as recommended by Ziołecki and Doruchowski (41). After dissection of the muscles, they were weighed on a laboratory scale to the nearest 0.1 g. Muscle sections of 50 g were collected to subject them to analysis of their chemical and mineral composition. These samples were frozen at −18°C and then lyophilised. Three replicates of 0.5 g of lyophilised tissue were mineralised with 5 ml of 65% nitric acid using a DK 20/26 mineraliser (Velp Scientifica, Usmate, Italy). After cooling, the solution was transferred to a volumetric flask and diluted in 25 mL of purified deionised water.

Analytical procedures. The content of basic nutrients (water, crude protein, crude fat, and crude ash) in the feed and muscles was determined according to AOAC procedures (1). The mineralisation of the samples was carried out on the DK20/26 mineraliser and nitric acid (Merck, Darmstadt, Germany) was used in the analytical procedures. The content of individual elements in the muscles was determined using inductively-coupled plasma atomic emission spectroscopy (ICP-AES) on a PS 950 ICP-OES (optical emission spectrometer) (Teledyne Leeman Labs, Mason, OH, USA). Different wave lengths were used the elements according to being evaluated 214.438 nm for Cd, 220.353 nm for Pb, 766.490 nm for K, 589.592 nm for Na, 279.553 nm for Mg, 213.856 nm for Zn, 393.366 nm for Ca, 224.700 nm for Cu, 206.149 nm for Cr, and 221.647 nm for Ni.

The limits of detection (LOD) for the individual elements were 0.306 μg L-1 for Cd, 0.030 mg L-1 for Pb, 0.013 mg L-1 for Ni, 0.015 mg L-1 for Cr, and 0.031mg L-1 for Mn. The total P content in the feed was determined colorimetrically according to the Fiske and Subbarow method (10) with a Helios Alpha UV-VIS apparatus (Spectronic Unicam, Cambridge, UK). The analytical procedures used are checked on an ongoing basis in intra-laboratory and inter-laboratory tests, using control samples spiked with different metal concentrations and certified reference materials (CRM). At the same time, blank samples were analysed to calibrate for the measuring glass and auxiliary materials used.

Statistical analysis. To determine the differences between the mean values of the analysed traits depending on the type of muscle, sex, and origin of the pheasants, a multifactor analysis of variance was performed. In order to verify the possible occurrence of differences between the averages, calculations were made using the Newman Keuls test in the Statistica 10.0 programme (StatSoft, Tulsa, OK, USA). The influence of origin, gender, and muscle type was considered significant at a level of $P \leq 0.05$.

Results

Wild birds were characterised by a lower thigh muscle mass than the farmed pheasants (Table 2). There were no such differences for the breast muscle for breeding and wild animals. In the males, a higher mass of both muscles was found than in the females. The breast muscles of the wild birds had more water than the farmed ones. The differences in water content between the breast and thigh muscles and between male and female birds were not statistically confirmed. The breast muscles of the male and female farm birds were measured to have more crude protein than the wild birds. There was no such difference for the thigh muscles, while these muscles contained less protein than the breast muscles. The birds from the farms yielded a higher fat content from both muscle types than the wild birds, with much more fat in the thigh than in the breast muscles. Both breast and thigh muscles showed a slightly larger crude ash constituent in the farm birds.

The content of macronutrients in the breast and thigh muscles of wild and farm birds varied considerably (Table 3). In all cases, the farm birds presented higher calcium content, but a statistically significant difference was found only in the male breast muscle. In relation to the wild animals, the farm birds' breast thigh muscles had more magnesium, with a slight variation of this feature between wild and farm birds within the sexes. In both the breast and thigh muscles, higher potassium content was found in the farm birds. In the breast muscles, these differences were statistically significant in males and females. Also in the breast muscle and in both sexes, higher sodium content was found. Higher and statistically significant differences were also found between the farm and wild birds in terms of phosphorus content in both muscle types.

Regardless of type, the muscles of the farm pheasants were characterised by significantly higher iron content than the wild ones, while the females were typified by a higher content of iron than the males (Table 4). A larger amount of zinc was assessed to be in both types of the farm birds' muscles than in the wild birds', with much more zinc found in the thigh muscles. Both the breast and thigh muscles were analysed to have higher copper accumulation in wild birds, with the exception of the thigh muscles in the males where the difference was statistically insignificant. The wild birds had also accumulated more manganese in the muscles of the breasts and thighs alike.

The wild birds were characterised by a higher lead content in both types of muscle (Table 5), and the differences between wild and farm birds were statistically significant. The cadmium in the breast muscles in the wild birds was greater, and this difference was statistically significant irrespective of sex. The differences in the contents of this element in the thigh muscles have not been statistically confirmed. The farm birds had a slightly higher level of chromium found in both the breast and thigh muscles, the latter also containing significantly more nickel than the breast muscles. Also higher in nickel, albeit slightly, was the result from the farm birds, regardless of the type of muscle and sex.

Table 2. Weight and chemical composition of pheasant muscles

Item	Bird origin	Breast muscle			Thigh muscle		
		♂	♀	Average	♂	♀	Average
Weight of muscle, kg	Wild	$0.264^a \pm 0.12$	$0.203^a \pm 0.15$	$0.234^x \pm 0.14$	$0.221^a \pm 0.17$	$0.171^a \pm 0.15$	$0.195^x \pm 0.12$
	Farm	$0.278^b \pm 0.19$	$0.209^a \pm 0.18$	$0.244^x \pm 0.18$	$0.239^b \pm 0.21$	$0.185^b \pm 0.1$	$0.212^y \pm 0.14$
	Average	$0.271^c \pm 0.16$	$0.206^d \pm 0.16$	$0.239^w \pm 0.15$	$0.230^c \pm 0.19$	$0.178^d \pm 0.13$	$0.204^z \pm 0.13$
Water, %	Wild	$74.13^a \pm 4.15$	$74.64^a \pm 4.17$	$74.38^x \pm 4.16$	$74.67^a \pm 3.82$	$74.76^a \pm 4.26$	$74.71^x \pm 3.94$
	Farm	$73.15^b \pm 4.28$	$73.49^b \pm 4.32$	$73.32^y \pm 4.19$	$74.31^a \pm 3.54$	$74.84^a \pm 3.72$	$74.58^x \pm 3.63$
	Average	$73.64^c \pm 4.19$	$74.06^c \pm 4.23$	$73.85^z \pm 4.17$	$74.49^c \pm 3.73$	$74.8^c \pm 3.96$	$74.62^z \pm 3.85$
Total protein, %	Wild	$24.21^a \pm 1.28$	$23.85^a \pm 1.33$	$24.03^x \pm 1.32$	$23.43^a \pm 1.09$	$23.36^a \pm 0.98$	$23.39^x \pm 0.92$
	Farm	$25.04^b \pm 0.87$	$24.82^b \pm 1.04$	$24.93^y \pm 0.98$	$23.85^a \pm 0.92$	$23.34^a \pm 1.02$	$23.59^x \pm 0.96$
	Average	$24.63^c \pm 0.98$	$24.34^c \pm 1.18$	$24.48^w \pm 1.15$	$23.64^c \pm 1.02$	$23.35^c \pm 0.97$	$23.49^z \pm 0.92$
Crude fat, %	Wild	$0.27^a \pm 0.04$	$0.29^a \pm 0.03$	$0.28^x \pm 0.03$	$0.44^a \pm 0.04$	$0.46^a \pm 0.04$	$0.45^x \pm 0.03$
	Farm	$0.39^b \pm 0.05$	$0.41^b \pm 0.04$	$0.4^y \pm 0.05$	$0.55^b \pm 0.05$	$0.57^b \pm 0.05$	$0.56^y \pm 0.05$
	Average	$0.33^c \pm 0.04$	$0.35^c \pm 0.04$	$0.34^w \pm 0.04$	$0.49^c \pm 0.04$	$0.52^c \pm 0.04$	$0.51^z \pm 0.04$
Crude ash, %	Wild	$1.07^a \pm 0.06$	$1.02^a \pm 0.05$	$1.05^x \pm 0.05$	$1.09^a \pm 0.07$	$1.08^a \pm 0.06$	$1.08^x \pm 0.06$
	Farm	$1.12^a \pm 0.07$	$1.11^a \pm 0.06$	$1.11^x \pm 0.06$	$1.11^a \pm 0.08$	$1.07^a \pm 0.09$	$1.09^x \pm 0.08$
	Average	$1.09^c \pm 0.06$	$1.07^c \pm 0.05$	$1.08^z \pm 0.05$	$1.10^c \pm 0.07$	$1.08^c \pm 0.07$	$1.09^z \pm 0.06$

a, b – different letters in the columns for the individual muscle groups of the females and males between the wild and farm birds mean statistically significant differences at $p \leq 0.05$
c, d – different letters in the rows mean statistically significant differences at $p \leq 0.05$ between the mean values for the males and females in particular muscle types
x, y – different letters in the columns between the average values for the individual muscle groups between the wild and farm birds mean statistically significant differences at $p \leq 0.05$
w, z – different letters in the rows mean statistically significant differences at $p \leq 0.05$ between the average values for the individual muscle types

Table 3. The content of selected macroelements (g kg^{-1} dry matter) in the muscles of pheasants

Item	Bird origin	Breast muscle			Thigh muscle		
		♂	♀	Average	♂	♀	Average
Phosphorus	Wild	$9.42^a \pm 0.74$	$9.15^a \pm 0.86$	$9.29^x \pm 0.79$	$9.18^a \pm 0.81$	$9.04^a \pm 0.79$	$9.11^x \pm 0.79$
	Farm	$10.12^b \pm 0.79$	$10.16^b \pm 0.94$	$10.14^y \pm 0.83$	$9.95^b \pm 0.81$	$9.93^b \pm 0.83$	$9.94^y \pm 0.82$
	Average	$9.77^c \pm 0.76$	$9.66^c \pm 0.9$	$9.72^z \pm 0.81$	$9.57^c \pm 0.81$	$9.49^c \pm 0.81$	$9.53^z \pm 0.81$
Calcium	Wild	$0.24^a \pm 0.02$	$0.29^a \pm 0.05$	$0.27^x \pm 0.04$	$0.47^a \pm 0.04$	$0.53^a \pm 0.04$	$0.5^x \pm 0.04$
	Farm	$0.34^b \pm 0.03$	$0.37^a \pm 0.06$	$0.35^x \pm 0.05$	$0.53^a \pm 0.05$	$0.6^a \pm 0.05$	$0.56^x \pm 0.05$
	Average	$0.29^c \pm 0.02$	$0.33^c \pm 0.05$	$0.31^w \pm 0.04$	$0.50^c \pm 0.04$	$0.57^c \pm 0.05$	$0.53^z \pm 0.04$
Magnesium	Wild	$0.93^a \pm 0.06$	$0.93^a \pm 0.07$	$0.93^x \pm 0.06$	$0.75^a \pm 0.02$	$0.86^a \pm 0.03$	$0.8^x \pm 0.03$
	Farm	$1.04^b \pm 0.08$	$0.99^a \pm 0.08$	$1.02^x \pm 0.08$	$0.94^b \pm 0.02$	$0.98^b \pm 0.02$	$0.96^y \pm 0.02$
	Average	$0.99^c \pm 0.07$	$0.96^c \pm 0.07$	$0.98^z \pm 0.07$	$0.85^c \pm 0.02$	$0.92^c \pm 0.02$	$0.88^z \pm 0.02$
Potassium	Wild	$14.23^a \pm 0.84$	$13.55^a \pm 1.03$	$13.91^a \pm 0.95$	$11.82^a \pm 0.92$	$12.34^a \pm 1.02$	$12.1^x \pm 0.97$
	Farm	$15.41^b \pm 0.87$	$14.62^b \pm 1.04$	$15.0^b \pm 0.97$	$12.35^a \pm 0.91$	$12.96^a \pm 0.94$	$12.72^x \pm 0.92$
	Average	$14.82^c \pm 0.85$	$14.08^c \pm 1.03$	$14.46^w \pm 0.96$	$12.09^c \pm 0.92$	$12.65^c \pm 0.99$	$12.4^z \pm 0.94$
Sodium	Wild	$1.05^a \pm 0.05$	$1.12^a \pm 0.05$	$1.08^x \pm 0.05$	$1.63^a \pm 0.09$	$1.99^a \pm 0.11$	$1.8^x \pm 0.09$
	Farm	$1.27^b \pm 0.17$	$1.34^b \pm 0.16$	$1.3^y \pm 0.16$	$1.71^a \pm 0.08$	$2.03^a \pm 0.12$	$1.89^x \pm 0.1$
	Average	$1.16^c \pm 0.15$	$1.23^c \pm 0.15$	$1.19^w \pm 0.15$	$1.66^c \pm 0.07$	$2.01^d \pm 0.11$	$1.85^z \pm 0.09$

a, b – different letters in the columns for the individual muscle groups in the females and males between the wild and farm birds mean statistically significant differences at $p \leq 0.05$
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w, z – different letters in the rows mean statistically significant differences at $p \leq 0.05$ between the average values for the individual muscle types

Table 4. The content of selected microelements (mg kg^{-1} dry matter) in pheasant muscles

Item	Bird origin	Breast muscle			Thigh muscle		
		♂	♀	Average	♂	♀	Average
Iron	Wild	$57.05^a \pm 5.02$	$79.09^a \pm 6.03$	$68.07^x \pm 5.53$	$82.08^a \pm 7.05$	$108.11^a \pm 9.04$	$95.09^x \pm 8.03$
	Farm	$98.11^b \pm 7.51$	$99.07^b \pm 8.02$	$98.59^y \pm 7.72$	$124.13^b \pm 9.05$	$126.09^b \pm 9.03$	$125.11^y \pm 9.04$
	Average	$77.6^c \pm 6.29$	$89.1^d \pm 7.03$	$83.34^w \pm 6.64$	$103.11^c \pm 8.06$	$117.31^d \pm 9.04$	$110.12^z \pm 8.55$
Zinc	Wild	$15.33^a \pm 1.33$	$16.01^a \pm 1.56$	$15.7^x \pm 1.47$	$21.74^a \pm 2.33$	$22.15^a \pm 2.01$	$21.9^x \pm 2.25$
	Farm	$18.67^b \pm 1.24$	$18.87^b \pm 1.88$	$18.76^y \pm 1.56$	$24.35^b \pm 1.98$	$24.88^b \pm 1.45$	$24.56^y \pm 1.87$
	Average	$17.0^c \pm 1.29$	$17.44^c \pm 1.73$	$17.22^w \pm 1.52$	$23.05^c \pm 2.16$	$23.52^c \pm 1.72$	$23.22^z \pm 2.06$
Cooper	Wild	$3.11^a \pm 0.34$	$3.68^a \pm 0.45$	$3.42^x \pm 0.38$	$2.15^a \pm 0.18$	$3.36^a \pm 0.24$	$2.76^x \pm 0.21$
	Farm	$1.61^b \pm 0.1$	$1.65^b \pm 0.18$	$1.63^y \pm 0.12$	$2.01^a \pm 0.11$	$2.11^b \pm 0.14$	$2.05^y \pm 0.12$
	Average	$2.36^c \pm 0.23$	$2.67^c \pm 0.34$	$2.54^z \pm 0.26$	$2.08^c \pm 0.15$	$2.74^d \pm 0.2$	$2.42^z \pm 0.17$
Manganese	Wild	$1.59^a \pm 0.27$	$1.05^a \pm 0.18$	$1.33^x \pm 0.22$	$2.57^a \pm 0.22$	$2.26^a \pm 0.28$	$2.43^x \pm 0.25$
	Farm	$0.83^b \pm 0.12$	$0.7^b \pm 0.09$	$0.77^y \pm 0.1$	$1.02^b \pm 0.16$	$0.99^b \pm 0.11$	$1.01^y \pm 0.12$
	Average	$1.22^c \pm 0.2$	$0.88^d \pm 0.11$	$1.05^w \pm 0.15$	$1.8^c \pm 0.19$	$1.63^c \pm 0.2$	$1.72^z \pm 0.18$

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w, z – different letters in the rows mean statistically significant differences at $p \leq 0.05$ between the average values for individual muscle types

Table 5. The content of heavy metals (mg kg^{-1} dry matter) in the muscles of pheasants

Item	Bird origin	Breast muscle			Thigh muscle		
		♂	♀	Average	♂	♀	Average
Lead	Wild	$0.81^a \pm 0.12$	$0.72^a \pm 0.12$	$0.76^x \pm 0.12$	$1.15^a \pm 0.15$	$1.13^a \pm 0.13$	$1.14^x \pm 0.13$
	Farm	$0.35^b \pm 0.12$	$0.35^b \pm 0.11$	$0.35^y \pm 0.11$	$0.58^b \pm 0.14$	$0.65^b \pm 0.12$	$0.61^y \pm 0.13$
	Average	$0.57^c \pm 0.12$	$0.54^c \pm 0.12$	$0.55^w \pm 0.12$	$0.86^c \pm 0.13$	$0.88^c \pm 0.12$	$0.87^z \pm 0.12$
Cadmium	Wild	$0.041^a \pm 0.01$	$0.061^a \pm 0.01$	$0.051^x \pm 0.02$	$0.011^a \pm 0.01$	$0.013^a \pm 0.002$	$0.012^x \pm 0.06$
	Farm	$0.002^b \pm 0.001$	$0.006^b \pm 0.002$	$0.004^y \pm 0.001$	$0.014^a \pm 0.02$	$0.018^a \pm 0.001$	$0.016^x \pm 0.05$
	Average	$0.022^c \pm 0.006$	$0.034^d \pm 0.006$	$0.028^w \pm 0.011$	$0.013^c \pm 0.01$	$0.016^c \pm 0.001$	$0.014^z \pm 0.05$
Chromium	Wild	$14.14^a \pm 2.04$	$14.88^a \pm 2.15$	$14.51^x \pm 2.09$	$16.66^a \pm 2.46$	$16.12^a \pm 2.32$	$16.38^x \pm 2.41$
	Farm	$18.29^a \pm 3.14$	$19.25^a \pm 3.26$	$18.78^x \pm 3.22$	$18.81^a \pm 3.12$	$17.84^a \pm 3.04$	$18.3^x \pm 3.1$
	Average	$16.23^c \pm 2.61$	$17.07^c \pm 2.72$	$16.66^z \pm 2.67$	$17.75^c \pm 2.8$	$17.0^c \pm 2.71$	$17.35^z \pm 2.77$
Nickel	Wild	$4.18^a \pm 1.45$	$4.22^a \pm 1.12$	$4.2^x \pm 1.31$	$7.12^a \pm 4.35$	$7.44^a \pm 3.12$	$7.28^x \pm 2.84$
	Farm	$4.58^a \pm 2.04$	$4.78^a \pm 1.95$	$4.74^x \pm 1.99$	$7.84^a \pm 2.18$	$7.43^a \pm 2.88$	$7.64^x \pm 2.91$
	Average	$4.43^c \pm 1.76$	$4.5^c \pm 1.54$	$4.47^w \pm 1.68$	$7.48^c \pm 3.42$	$7.43^c \pm 3.1$	$7.46^z \pm 2.89$

a, b – different letters in the columns for the individual muscle groups in the females and males between the wild and farm birds mean statistically significant differences at $p \leq 0.05$
c, d – different letters in the rows mean statistically significant differences at $p \leq 0.05$ between the mean values for the males and females in particular muscle types
x, y – different letters in the columns between the average values for individual muscle groups between the wild and farm birds mean statistically significant differences at $p \leq 0.05$
w, z – different letters in the rows mean statistically significant differences at $p \leq 0.05$ between the average values for individual muscle types

Discussion

The content of nutrients and minerals, including heavy metals, in the muscles of pheasants allows the birds' nutrition, their condition, and the degree of environmental contamination to be assessed. In the presented studies, significant differences were found between the weight and mineral composition of the wild pheasants' breast and thigh muscles and those of the pheasants raised under farm conditions. These differences are predicated on the different feeding regimes of birds kept on farms and those in their natural habitat, as well as on age and sex, which has been shown in the studies of other authors (18, 23, 27). The males were characterised by a higher mass of breast and thigh muscles in relation to the females, which was also seen in studies by Kotowicz *et al.* (21). Research by Strakova *et al.* (36) showed that the enrichment of bird nutrition significantly influenced the chemical composition of the muscles, regardless of the species. These studies also showed protein to be more abundant in the dry mass of the breast muscles than that of the thigh muscles, and fat to be less abundant, which was confirmed in our research. Franco and Lorenzo (12) also showed a higher protein content and lower fat content in the breast muscles compared to the thigh muscles in farmed pheasants, while Večerek *et al.* (40) confirmed this dependence regardless of the term of slaughter. These authors found significantly more fat in the thigh muscles, which at 90 days of fattening in females was 57.5 g/kg and in males was 45.2 g/kg, in comparison in the breast muscles fat was 7.79 g/kg and 8.87 g/kg, respectively. The results of this research showed a higher protein content in the breast muscle in the farm birds, which proves that nutrition plays a decisive role in the mass and composition of pheasant muscles (16). The demonstrated high protein content combined with low fat content makes this meat much more valuable than broiler meat and may be a desirable part of the human diet (11, 12, 36).

The assessment of the quality of meat of particular animal species, including wild-caught ones, concerns mainly the protein and fat content, amino acid and fatty acid profile, and mineral accumulation, including heavy and toxic metals (3, 4, 20, 25). The content of macroelements found in our studies was at a level similar to that reported by other authors (35, 36); however, for some elements, significant differences were found depending on the sex and maintenance system. More significant differences in the content of macroelements between farm and wild birds were found for the breast muscles than the thighs, mainly for the males. The level of phosphorus was distinctly higher in farm birds than in wild birds regardless of sex and muscle type. This indicates a much better supply of this element to farm animals than to wild ones. The sex of the birds and the type of the muscles did not significantly affect the level of this element, which was confirmed by the results of studies by Strakova *et al.* (36), the authors of which found significantly higher values for pheasants than for slaughter chickens. The observed differences in the calcium content between the muscles in favour of the thigh muscles (0.31 g/kg *vs*. 0.53 g/kg dry matter – DM) were also confirmed by the studies by Strakova *et al.* (36) in which the values obtained were significantly higher (0.62 g/kg *vs*. 1.3 g/kg DM). These differences could be a consequence of the birds being supplied with this element, their living conditions, and slaughter weight. The studies of these authors showed significantly lower calcium content in pheasant breast muscles than those of broilers. The amount of magnesium in both types of meat was higher in farm birds, while slightly higher values were recorded for the breast muscles. The obtained values for both muscles and sexes were similar to those given by Mieczkowska *et al.* (27) but much lower than those in the studies by Strakova *et al.* (36), while for thigh muscles, the level of this element was close to the values given by Stanaćev *et al.* (35). Sodium levels were clearly higher in thigh muscles than in breast muscles, as confirmed by research by Mieczkowska *et al.* (27), with a much higher concentration found in captive bred birds.

The content of micronutrients in the muscles of pheasants was interesting, and not always unambiguously interpreted. Iron and zinc were higher in farm animals, while copper and manganese were higher in wild birds. Compared to breast muscles, the thigh muscles showed a similar copper level but significantly higher levels of iron, zinc, and manganese. These results are similar to those reported by certain authors but are also significantly different to those of others (11, 27, 35, 36). This may be due to the supply of these elements in the feed for farmed birds, and its availability in the natural environment, as well as the sex and age of the slaughtered pheasants. Female pheasants showed higher iron content in both breast muscles (89.10 mg/kg *vs*. 77.60 mg/kg DM) and thigh muscles (117.31 mg/kg *vs*. 103.11 mg/kg DM). Research by Mieczkowska *et al.* (27) also a confirmed higher iron content in the thigh muscles (110 mg/kg for males and 100 mg/kg DM for females) than the breast (70 mg/kg for males and 60 mg/kg DM for females), with the differences between sexes not being statistically significant. The iron in the breast muscles and thighs of pheasants from Serbia (35) was clearly less than that in the current research. The zinc was significantly more in the thigh muscles than in the breast muscles (23.22 mg/kg *vs*. 17.22 mg/kg DM), which is confirmed by Stanaćev *et al.* (35) and Franco and Lorenzo (12) whose results were 2–3 times lower in females and males compared to the results of Mieczkowska *et al.* (27). The level of copper was significantly higher in wild and farm birds both in the breast muscles (3.42 mg/kg *vs*. 1.63 mg/kg DM) and in the thighs (2.76 mg/kg *vs*. 2.05 mg/kg DM), and the values obtained were significantly lower than those given by Franco and Lorenzo (12) and Stanaćev *et al.* (35). In wild birds, the weight of manganese in both muscle groups was significantly higher than in the case of farmed ones: 1.33 mg/kg *vs*. 0.77 mg/kg DM for the breast muscles and 2.43 mg/kg *vs*. 1.01 mg/kg DM for the thigh muscles. A similar level of manganese was found in studies by Franco and Lorenzo (12) for farm birds, and Stanaćev *et al.* (35) showed much higher values in pheasants from Serbia.

Wild animals are exposed to continuous pressure from environmental factors, so they can be used as a natural bioindicator of environmental contamination (19, 22, 26, 30, 37). The most attention is paid to the accumulation of lead and cadmium, legislation for which is included in Commission Regulation (WE) No. 1881/2006 (6), where for poultry, the permissible lead content is 0.10 mg/kg of fresh weight, and for cadmium - 0.05 mg/kg of fresh weight. The lead content of farm pheasants in both evaluated muscles was slightly higher than the acceptable recommendations in this respect, with the higher reference value being exceeded for the thigh muscles. Clearly more lead was found in wild pheasant carcasses because it was introduced by the shot penetration of the birds, and the differences regardless of sex and muscle were statistically confirmed. The lead content in pheasants shot and killed in eastern Slovakia was detected as significantly greater only in the breast muscles (20). The results of research conducted in England, Scotland, and Wales on the content of lead in the tissues of various species of wild animals showed that on average there were 3.3 shots weighing 0.42 g in the muscles of one shot pheasant. The same studies showed that in 54% of pheasants, the lead content was higher than 0.1 mg/kg of fresh weight, and in another 10%, this level was higher than 1 mg/kg of fresh muscle mass (29). Cadmium had accumulated to a significantly larger extent in the breast muscles (0.028 mg/kg DM) than in the thighs (0.014 mg/kg DM), but it was within the values given in the Commission Regulation. In addition, the breast muscles of wild birds contained significantly more cadmium than farmed ones, with similar amounts in the thigh muscles. Similar trends regarding the amount of cadmium in thigh muscles were reported in studies by Koréneková *et al*. (20). The nickel content did not differ significantly in wild and farm pheasants, and gender did not have a significant impact on its quantity in either muscle type. Significant differences occurred between muscles where 7.46 mg/kg DM was found in the thigh muscles and 4.47 mg/kg DM in the breast muscles. Slightly lower values were recorded in the studies of Koréneková *et al*. (20), with significantly more nickel in the breast muscle of wild birds than in breeding birds. This was a consequence of the inclusion of this element in the shot which hit the birds. The male and female farm birds were characterised by a slightly higher content of chromium in both muscle types than the wild pheasants, but the differences were not statistically confirmed. This trend may have been the result of the low amount of chromium compounds in the wild bird habitat.

The presented results confirm the high quality and usefulness of the meat of pheasants as a dietary element, both wild and farm-bred. This meat has a recommendable content of macro- and trace elements as well as the permissible content of elements of heavy metals, with the exception of lead in wild birds. The level of heavy metals, especially lead in wild birds, can be a natural bioindicator of the occurrence of these metals in of the environment, as well as remnants from shot. The results of our research confirm the quality and suitability of pheasant meat as a component of the human diet (3, 4, 18, 20, 23, 25, 27). An increased content of lead slightly above the reference values, especially in wild birds after shooting, should not have a negative impact on the health of consumers. This is confirmed by the results of Haldimann *et al*. (15), which showed no significant differences between the content of lead in the blood of people eating venison and those without this meat in their diet.

The obtained results allow the following conclusions to be formulated: farm pheasants were characterised by a larger weight of breast and thigh muscle, which was conditioned by the specifics of their feed and their lesser locomotor activity. Captive bred pheasants yielded a slightly higher protein content, and a significantly higher fat content, from both types of muscle. The breast muscles had stronger positive dietary attributes than thighs because they contained much less fat (3.4 g *vs*. 5.1 g per kg of natural muscle mass). The level of macroelements depended on the muscle type and origin of the birds. Less weight of calcium and sodium and more of potassium was typical of the breast muscles when compared to the thigh muscles, with a slight variation in calcium and potassium due to the sex of the birds. The content of trace elements also varied by origin, gender, and muscle type. The thigh muscles had a characteristic higher content of iron, zinc, and manganese than the breast muscles. The wild birds were tested to have lower muscular iron and zinc, and higher copper and manganese regardless of the type of muscle. In the breast muscles of the females of both origins, higher content of iron and lower content of manganese were found. Wild birds contained more cadmium in the breast muscles and lead in both muscles than the farmed animals, while the content of lead slightly exceeded the admissible values for wild birds, which may be a confirmation of secondary lead contamination from bird shot. There were no significant differences in the content of chromium and nickel between wild and farm birds.

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