Scifood
vol. 20, 2026, p. 74-91
https://doi.org/10.5219/scifood.94
ISSN: 2989-4034 online
https://scifood.eu

Received: 28.12.2025
Revised: 29.1.2026
Accepted: 2.2.2026
Published: 3.2.2026

The safety of wild boar (*Sus scrofa*) meat hunted in different European countries

Władysław Migdał, Čedomir Radović, Vladimir Živković, Łukasz Migdał

ABSTRACT

The wild boar (*Sus scrofa*) is a popular game animal worldwide. Boar populations in Europe and Asia are numerous and widespread. However, these animals pose numerous problems: they damage agricultural crops, spread infectious diseases that are dangerous to pigs (e.g., African swine fever, ASF), encroach on human settlements, cause traffic accidents, and are an increasing threat to humans. Attempts to reduce the number of wild boars have a low success rate, since, thanks to their rapid reproduction, their herds quickly recover after periods of intensive shooting. In addition, they perform well even in hostile environments and readily colonize new areas. Hunting and systematic culling of wild boars are aimed at reducing their numbers and population density. In 2019-2023, the annual harvest of wild boar carcasses ranged from 221,000 to 420,000. After mandatory veterinary inspection, wild boar meat can be a more environmentally friendly, low-cost alternative to pork. Considering the findings of various authors, the rules for marketing and consuming this meat should be followed. Only meat from wild boar carcasses that have undergone mandatory testing for *Trichinella spiralis* and *Alaria alata* should be consumed. The consumption of wild boar offal, especially liver and kidneys, should be strictly avoided due to the accumulation of heavy metals and radioactive contamination in these organs. Venison is an organic food, free of antibiotics and growth promoters. However, due to the risks presented, it requires special treatment and veterinary control.

Keywords: wild boars, meat, safety

INTRODUCTION

The wild boar (*Sus scrofa*) is a common wild mammal belonging to the Suidae family and is considered the ancestor of domestic pigs. The natural range of wild boars extends from North Afica to South Asia. The wild boar is a highly adaptable species, found in many habitats (from semi-desert areas to swamps and forests), and has enormous reproductive capacity **[1]**. Veličković et al. **[2]** observed a divergent population structure and identified 14 wild boar subpopulations. In Poland, wild boars are common throughout the country, from the Baltic coast to the mountainous areas. They are game animals and, although they play an important role in forest ecosystems, their growing populations and behavior can cause conflicts, particularly with agriculture. In the past, wild boars fed at night on the edges of forests, penetrating fields in search of food, while during the day they stayed in forest refuges. It is important to emphasize the positive role of wild boars in forestry and hunting, which consists of: rooting or deep digging of the upper layers of forest soil and mixing litter with mineral soil, as well as eating certain species of harmful forest insects and small rodents. In addition, wild boars maintain hygiene in the hunting ground by eating dead animals and searching for and eating sick mammals and birds, thereby reducing the possibility of disease outbreaks **[3]** and **[4]**. However, their behavior has changed completely in recent years. The abundance of food around human settlements (allotments, garbage containers, which contain more food) and in fields has led to the emergence of packs that spend most of their time outside the forest, among fields of grain and corn. A study conducted in Poland found that the number of wild boars harvested was positively correlated with the expansion of maize crops **[5]**. Wild boars, including sows with piglets, are increasingly being spotted during the day in fields, meadows, orchards, and gardens, as well as in cities, where they come to feed in garbage cans and landfills. It is estimated that between 1,000 and 2,000 wild boars live in the capital of Poland, Warsaw. Global warming, snowless, warm winters, an abundance of high-calorie food, thoughtless feeding of wild boars in cities and on tourist trails, a lack of natural enemies, and an increasing amount of wasteland, which provides ideal hiding places, have meant that wild boars are no longer afraid of humans, and their population is growing rapidly. Therefore, wild boars are now increasingly seen as pests. Wild boars are considered one of the "100 worst invasive species in the world" because they are unique among other problematic terrestrial invasive species in that they are omnivorous generalists and function as both large predators and herbivores throughout their native and non-native range **[6]**, and **[7]**. According to Risch et al. **[8]**, wild pigs threaten 672 taxa in 54 different countries across the globe. Most of these taxa are listed as critically endangered or endangered, and 14 species have been driven to extinction as a direct result of impacts from wild pigs **[8]**. Across Europe, the wild boar population is growing steadily **[1]** and **[9]**. There was a sharp increase in the 1960s and 1970s, followed by a period of stabilization in the 1980s. Since the 1990s, there has been a sharp increase in the wild boar population **[9]**, and **[10]**. Wild boars are responsible for damage to arable land and serious impacts on biodiversity **[11]**. In addition, there has been an increase in the number of road accidents involving wild boars, as well as concerns about disease transmission, which threatens public health **[12]** and pig farming in many European countries **[13]**. Between 2014 and 2020, African Swine Fever virus (ASFV) infected wild boar populations in eleven European Union (EU) countries: Estonia, Lithuania, Latvia, Poland, the Czech Republic, Bulgaria, Belgium, Romania, Hungary, Slovakia, and Germany. Until July 30th, 2019, when the first case of African swine fever (ASF) was confirmed, Serbia was ASF-free **[14]**. A similar situation occurred in Slovakia, where ASF appeared in August 2019 and the wild boar population reached its highest level in six decades **[15]**. This led to the spread of African swine fever among pigs, threatening to wipe out pig herds. Many European countries are implementing programs to control wild boar populations. In June 2021, Denmark announced the culling of the last wild boar on its territory **[16]**. An integrated approach to wild boar population management should take into account the impact of biometeorological, demographic, and ecological factors, as well as the risk of epidemics such as African swine fever, as the combined impact of biometeorological and demographic factors is greater in regions affected by African swine fever **[17]**. Regulating the wild boar population is difficult due to the species' high reproductive rate and intelligence, which limit the effectiveness of hunting **[18]**. Therefore, to effectively control the wild boar population, it is crucial to coordinate hunting pressure evenly across large areas. The culling of wild boars for the purpose of depopulation means that more wild boar meat is being obtained, which should lead to an increase in its consumption. Compared to domestic pigs, wild boars present a higher degree of carcass fatness and larger loin areas, more slow-twitch oxidative (I) and fast-twitch oxidative glycolytic (IIA), and darker, less tender, and leaner meat **[19]**.

Consumption of game

Although Poland is one of the leading producers and exporters of game meat in Europe, its consumption in the country is very low, at around 0.08 kg/person/year **[20]**, lower than in the Czech Republic (1.1 kg/person/year), Slovakia (0.56 kg/person/year) **[21]** or Croatia (0.55 kg/person/year) **[22]**. Of the 3,445 respondents from 10 European countries surveyed, 510 (14.8%) had never consumed game meat **[21]**. Game consumption depends to the greatest extent on the geographical location – inhabitants of South-Eastern European countries consume more of it than inhabitants of Central European countries [21]. The low consumption of game meat among Poles is attributable to its high price and limited availability in retail outlets, as well as the abundance of cheaper livestock meat on the market **[23]**. In addition, Polish game meat is an export commodity. Nearly 95% of game meat is exported, with 70% going to the German market **[23]**. Wild boar meat is suitable for processing **[24]**, and **[25]** and is used in the production of luxury smoked meats (ham, tenderloin), sausages (dry-cured, semi-dry-cured, medium- and finely-ground, steamed), as well as offal cold cuts, pâtés, and preserves **[23]**. Consumers express concerns about potential risks associated with the consumption of game meat, such as zoonoses, microbiological contamination, and the presence of heavy metals and pesticides; therefore, it is recommended that consumption be limited among breastfeeding women and children **[26]**, and **[27]**. Wild boar meat must be tested by veterinarians for the presence of spiral worms. These worms are found in both forest and domestic environments, and their main reservoirs are wild animals, mice, and rats. Forest areas provide favorable conditions for the spread of *Trichinella spiralis* and *Alaria alata*, with wild boars (*Sus scrofa*) and foxes (*Vulpes vulpes*) being the most important vectors **[28]**, and **[29]**. The levels of persistent organic pollutants in wild animals reflect the environmental contamination with these compounds. Wild animals and game are good indicators of environmental contamination by chlorinated hydrocarbons, and game is a major secondary source of human contamination; therefore, monitoring game seems justified. Since wild boars feed on farmland using a variety of foods, the chemical composition, quality, and safety of their meat may vary.

Heavy metals and arsenic

Consumers are expressing concerns about potential risks associated with consuming game meat, including heavy metals and pesticides **[27]** and **[30]**. The following tables present the concentrations of heavy metals and arsenic in the muscle tissue (Table 1 and Table 2), the kidney (Table 3), and the liver (Table 4) of wild boars shot in various European countries. The accumulation of Cd and Hg in the kidneys of wild boars was higher than that found in the liver and muscle tissue. In many cases, the average concentrations of Cd and Hg in the kidneys and Pb in the muscle tissue exceeded the maximum permissible values established for animals intended for human consumption, in accordance with EU food safety standards. The accumulation of lead and cadmium in the muscles and liver of wild boars increases with age **[31]**. Cammilleri et al. **[32]** found higher trace metal and metalloid content in wild boars from industrial regions of Southern Italy. Bąkowska et al. **[33]** also found the highest concentrations of Cd in wild boars hunted in the southern regions of Poland, in areas characterised by the highest degree of industrialisation and the presence of heavy industry. However, these authors also found high concentrations of cadmium in wild boars hunted in north-eastern Poland, a region commonly considered free of pollution. Vidosavljević et al. **[34]** found the presence of heavy metals (Cd, Hg, and Pb) and the metalloid As in meat and offal samples from all studied locations in Papuk Nature Park (Croatia). Since the area of Papuk Nature Park is uninhabited and there are no industry or roads, the elevated metal concentrations in wild boar tissues could not be related to anthropological influences **[34]**. High lead content in venison may be the result of secondary lead contamination from missiles.

Based on the data summarized in Tables 1 and 2, the muscle tissue of wild boars generally contained lower concentrations of heavy metals compared to internal organs; however, substantial variability was observed among countries and regions. Lead was the most problematic element in muscle tissue, with several studies reporting concentrations that exceeded EU maximum limits, particularly in Hungary, Croatia, Italy (Sardinia), and Poland. These elevated Pb levels are frequently attributed not only to environmental exposure but also to secondary contamination caused by the fragmentation of lead-based ammunition during hunting. Cadmium concentrations in muscle tissue were typically lower than in the kidneys and liver; however, in certain regions, including parts of Poland, Slovakia, Turkey, and Romania, Cd levels approached or exceeded regulatory thresholds. Arsenic and mercury were generally detected at lower concentrations or were below detection limits in muscle tissue, although sporadic elevated values were reported even in areas considered environmentally clean.

The kidney (Table 3) was identified as the primary organ of accumulation for cadmium and mercury, confirming its role as a critical biomarker of long-term exposure. In several European countries, including Poland, Slovakia, Spain, Sweden, and Turkey, cadmium concentrations in kidneys were markedly higher than those measured in muscle or liver and often exceeded permissible levels for edible offal. Mercury was also frequently detected in kidneys, although its concentrations showed considerable interregional variability. These findings indicate chronic exposure of wild boars to environmental contaminants, reflecting both natural geochemical background and diffuse pollution sources.

Liver tissue (Table 4) exhibited intermediate accumulation patterns, with cadmium and lead being the dominant contaminants. Particularly high Cd and Pb concentrations were reported in Poland, Italy (Sardinia), Spain, and Turkey, with some values exceeding 1000 μg/L. Although the liver plays a central role in detoxification, its contaminant burden further underscores the potential health risks associated with the consumption of wild boar offal. Overall, the results demonstrate that heavy metal and arsenic contamination of wild boar tissues is widespread across Europe and is influenced by a combination of environmental factors, animal age, feeding habits, and hunting practices. These findings highlight the importance of regular monitoring and risk assessment of game meat and edible offal intended for human consumption.

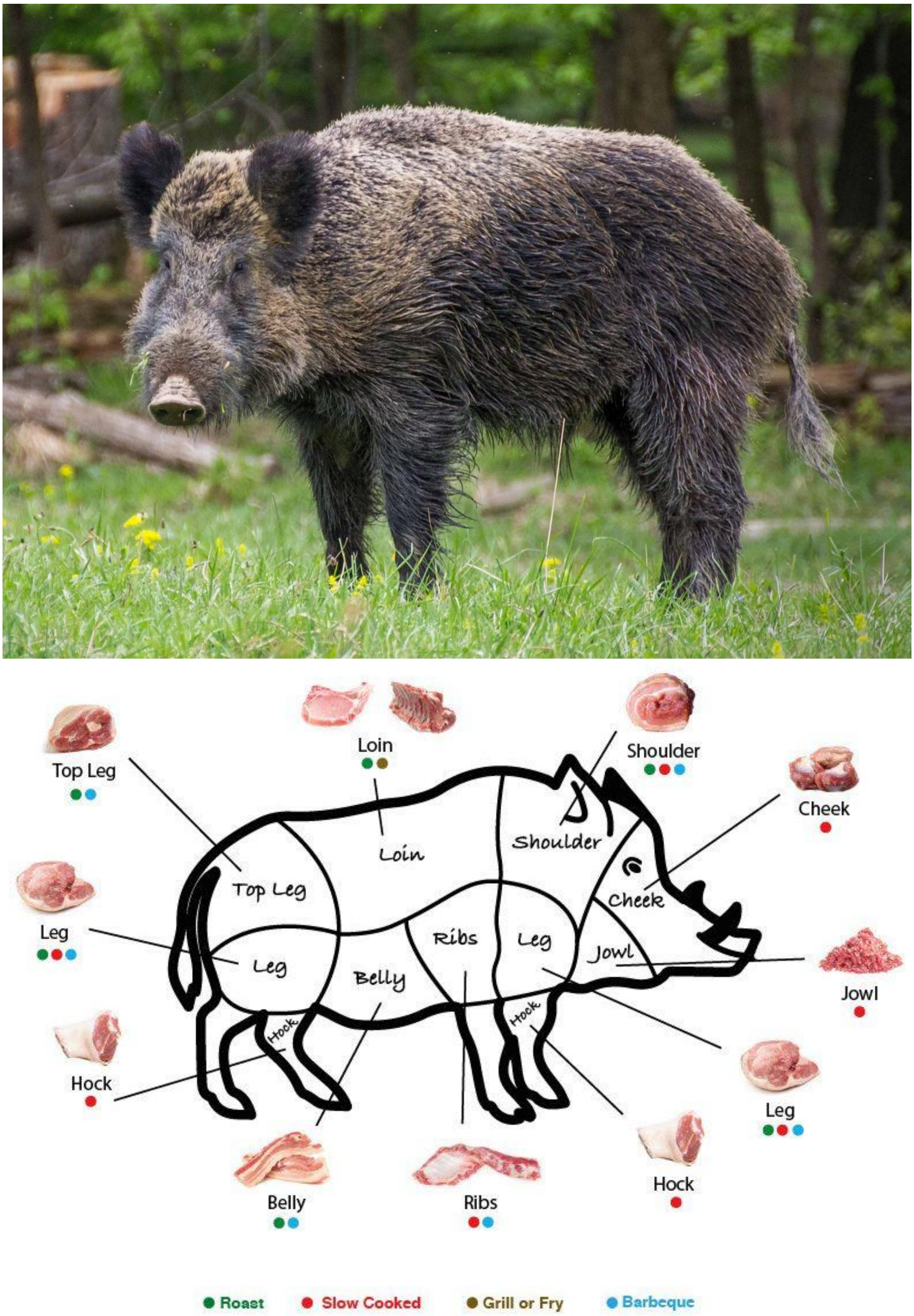

Figure 1 Wild boar *Sus scrofa* and its meat parts (https://www.rudfordfarms.uk/).

Table 1 Content of heavy metals and arsenic in the muscle tissue of wild boars hunted in various European countries.

Characteristic	European countries						
	Poland **[35]** mg/kg	Poland **[36]** mg/kg	Slovakia **[37]** mg.kg		Slovakia **[38]** µg/g w.w.	Hungary **[39]** mg/kg w.w	Romania **[40]** mg/g
Hunting season	September 2011-December 2013	2010-2011	2014/2015 – 2017/2018,		November and December of 2009 and 2010	2018 August and September	winter 2010–2021
Hunting area	Upper Silesia, Turoszow Coal Basin, Masurian Lake Distric	Podkarpacie Subcarpathia south-eastern Poland	Tatra National Park	Zemplin	region of Nitra and Topolcianky	Central Transdanubia Region	North-Eastern Romania
Arsenic (As)	nd	nd	0.06-2.94	0.001-0.02	nd	<0.5	nd
Cadmium (Cd)	0.001 - 0.140	0.01-0.06	0.003-2.63	0.024-1.53	0.043-0.373	<0.05	0.01-0.98
Lead (Pb)	0.002 - 0.130	0.06-0.18	0.009-1.894	0.001-0.36	0.039-61.3	0.22 - 0.36	0.025-0.302
Mercury (Hg)	0.001 - 0.035	nd	0.02-0.871	0.001-0.137	0.000-0.251	<0.5	nd
Chromium (Cr)	nd	nd	nd	nd	nd	nd	nd

Characteristic	European countries						
	Croatia **[41]** (mg/kg)	Croatia **[34]** mg/kg	Austria **[42]** mg/kg wet mass	Italy **[43]** mg kg^{-1} ww	Italy **[44]** mg/kg w.w.	Italy Sardinia **[45]** mg/kg dw	Turkey **[46]** mg/kg
Hunting season	2008/2009	nd	2012-2013	November 2005-January 2006	nd	2022–2023	September 2013-February 2014
Hunting area	between the Sava and Drava Rivers	Papuk Nature Park	Eastern Austria	Viterbo Province	Molise - Bagnoli del Trigno and Roccavivara	northern Sardinia	Kırıkkale province
Arsenic (As)	nd	0.012-0.286	0.012± 0.011	nd	nd	nd	nd
Cadmium (Cd)	0.0002–0.428	0.004-0.672	0.002± 0.001	0.031–0.381	0.001	nd	0.51±0.02
Lead (Pb)	0.001–1.01	0.03-9.1	0.015± 0.017	0.080 – 0.226	0.011	0.011-85.76	0.44±0.17
Mercury (Hg)	0.001–0.036	0.005-0.103	0.008± 0.005	nd	nd	nd	nd
Chromium (Cr)	nd	nd	0.007± 0.006	0.069 – 0.692	0.066	nd	1.35±0.59

Note: nd - no data.

Table 2 Content of of heavy metals and arsenic in the tissues of wild boars hunted in various regions of Poland (µg.kg^{-1} fresh meat) (n=40) **[47]**.

Heavy metals	**Voivodeships**					
	DolnośląskieLower Silesia n=7	Opolskie Opole n = 7	Śląskie Silesia n = 7	Małopolskie Lesser Poland n =6	Podkarpackie Subcarpathia n =7	Lubelskie Lublin n =6
Arsenic (As) µg.kg^{-1}	6.68 (1.0-19.6)	4.28 (2.7 - 7.0)	9.78 (1.9-38.5)	12.6 (9.6-17.8)	6.06 (2.0-13.1)	7.4 (5.0-9.8)
Cadmium (Cd) µg.kg^{-1}	4.13 (2.0-12.4)	4,87 (1.0 - 12.4)	3.36 (2.0-5.8)	3.1 (1.9-4.5)	4.22 (1.8-8.7)	7.1 (3.0-11.2)
Lead (Pb) µg.kg^{-1}	42.45 (11.1-82.0)	18.75 (2.0 -70.0)	35.06 (4.9-63.9)	22.53 (11.2-44.8)	14.0 (10.9-21.0)	36.4 (31.0-41.8)
Mercury (Hg) µg.kg^{-1}	7.3 (1.0-16.3)	3.43 (1.1-6.0)	3.94 (1.0-7.7)	7.53 (6.3-9.0)	8.3 (1.3-13.5)	7.65 (6.3-9.0)

Table 3 Content of heavy metals and arsenic in the kidney of wild boars hunted in various European countries.

Characteri-stic	**European countries**				
	Poland **[35]** µg.kg^{-1}	Serbia **[48]** µg.kg^{-1}	Croatia **[41]** µg.kg^{-1}	Croatia **[49]** µg.kg^{-1}	Romania **[40]** µg.kg^{-1}
Hunting season	September 2011- December 2013	nd	2008/2009	December 2008 and January 2009	winter 2010–2021
Hunting area	Upper Silesia, Turoszow Coal Basin, Masurian Lake Distric	eight localities in Serbia	between the Sava and Drava Rivers	eastern Croatia	North-Eastern Romania
Arsenic (As)	nd	nd	nd	0.0004–0.054	nd
Cadmium (Cd)	0.422-245. 50	0.18-9.77	0.003–13.67	0.001–8.233	0.113–1.988
Lead (Pb)	0.013- 6.930	nd	0.001–3.89	0.001–0.792	nd
Mercury (Hg)	0.005 - 0.364	0.01-0.56	0.001–0.984	0.001–3.661	nd

Characteri-stics	**European countries**				
	Slovakia **[50]** mg.kg^{-1}	Slovakia **[38]** mg.g^{-1} w.w.	Spain **[51]** mg.kg^{-1} dry weight	Sweden **[52]** mg.kg^{-1} wet weight	Turkey **[46]** mg.kg^{-1}
Hunting season	1998–1999	November and December of 2009 and 2010	February 2021	October and December 2015	September 2013-February 2014
Hunting area	Central Zemplín	region of Nitra and Topolcianky	Castile and León region	Skåne, Blekinge, Uppland	Kırıkkale province
Arsenic (As)	0.01-0.82		0.200 ± 0.087	<LOQ–0.08	nd
Cadmium (Cd)	0.14-2.68	0.36-8.82	7.063 ± 7.271	0.16–12.8	3.05±0.99
Lead (Pb)	0.14-0.85	0.049-1.10	0.275 ± 0.171	0.03–1.01	0.52±0.18
Mercury (Hg)	0.05-1.60	0.001-0.739	nd	nd	0.12±0.17
Chromium (Cr)	0.09-0.48	nd	0.184 ± 0.189	nd	1.82±1.79

Note: nd - no data.

Table 4 Content of heavy metals and arsenic in the liver of wild boars hunted in various European countries (mg/kg).

Characteristic	European countries				
	Poland **[35]** mg.kg^{-1}	Serbia **[48]** mg.kg^{-1}	Slovakia **[50]** mg.kg^{-1}	Slovakia **[38]** µg.g^{-1} w.w.	Croatia **[49]** mg.kg^{-1}
Hunting season	September 2011-December 2013	nd	1998–1999	November and December of 2009 and 2010	December 2008 and January 2009
Hunting area	Upper Silesia, Turoszow Coal Basin, Masurian Lake Distric	eight localities in Serbia	Central Zemplín	region of Nitra and Topolcianky	eastern Croatia
Arsenic (As)	nd	nd	0.01-0.90	nd	0.0001–0.0680
Cadmium (Cd)	0.029-39.60	0.03-1.26	0.12-0.94	0.190-1.92	0.022–1.616
Lead (Pb)	0.012 - 9.672	nd	0.06-0.43	0.040- 1.29	0.001–0.618
Mercury (Hg)	<0.001-0.231	0.01-0.08	0.01-0.48	0.003-0.113	0.001–0.146
Chromium (Cr)	nd	nd	0.02-0.49	nd	nd
Characteristic	**European countries**				
	North Macedonia **[53]** mg.kg^{-1}	Italy **[43]** mg.kg^{-1} ww	Italy Sardinia **[45]** mg.kg^{-1} dw	Spain **[51]** mg/kg dry weight	Turkey **[46]** mg.kg^{-1}
Hunting season	2017- 2021	November 2005-January 2006	2022–2023	February 2021	September 2013-February 2014
Hunting area	North Macedonia Bitola and Gevgelija	Viterbo Province	northern Sardinia	Castile and León region	Kırıkkale province
Arsenic (As)	0.001- 0.122	nd	nd	0.096 ± 0.048	nd
Cadmium (Cd)	0.037- 1.203	0.008–0.380	nd	0.701 ± 0.635	0.61±0.15
Lead (Pb)	0.021- 1.095	0.179–0.564	0.030 – 251.19	0.299 ± 0.402	0.75±0.51
Mercury (Hg)	0.0026- 0.169	nd	nd	nd	nd
Chromium (Cr)	nd	<LOD-0.626	nd	0.085 ± 0.034	1.30±0.77

Note: nd - no data.

Radionuclide content

The accumulation of ^{137}Cs in game species has been studied worldwide following the Chernobyl disaster. After deposition, radiocesium remains in the environment for a long time and continuously enters the food chain, which is why game species are particularly susceptible to ^{137}Cs accumulation – Tables 5 and 6. According to Hohmann and Huckschlag **[54]** and Dvořák et al. **[55]**, radiocaesium enters the muscles of wild boars through the ingestion of the underground fungus Elaphomyces granulatus. Radionuclide ^{137}Cs is monitored in food for food-chain contamination and as a potential risk to human health **[56]**. A limit of 600 Becquerels per kilogram (Bq/kg) for the sum of cesium-137 (^{137}Cs) and cesium-134 (^{134}Cs) in food products is a regulatory limit used by some countries, such as the European Union, to ensure consumer safety **[57]**. Wild boars (Sus scrofa) are notorious for accumulating high contamination levels of ^{137}Cs in their meat. Kouba et al. **[56]**, examining the activity of ^{137}Cs in the meat of 654 wild boars from the Novohradské Mountains in the South Bohemian region, found that the permissible level of ^{137}Cs of 600 Bq·kg-1 was exceeded in 238 samples (36.4%) of the meat of hunted wild boars. Oloś and Dołhańczuk-Śródka **[58]**, examining the activity of ^{137}Cs in samples of meat from wild animals obtained in the areas referred to as Anomalia Opolska (Opole anomaly), located in south-west Poland, found that the activity of ^{137}Cs ranged from 0.14 to 592 Bq/kg. The "Opole anomaly" is a term referring to the significant radioactive contamination in the Opole region caused by radioactive fallout from the Chernobyl disaster, resulting from heavy rainfall. Similar regions can be found in other countries, e.g. the Fužine area in Croatia **[59]** or Novohradské Mountains in the South Bohemian region **[56]**, where the values of ^{137}Cs in wild boar meat are several hundred Bq kg^{-1}. Czerski et al. **[60]** found three times higher concentrations of Cs-137 in the muscles of wild boars than in roe deer and red deer hunted in Poland between 2015 and 2022. The highest concentration of Cs-137 in the muscles of a wild boar hunted in 2021 was 4195 ± 372.0 Bq/kg **[60]**.

Table 5 Content of cesium ^{137}Cs and cesium ^{134}Cs in the tissues of wild boars hunted in various European countries (Bq/kg fresh meat).

Characteristics	**European countries** Poland **[47]**	Serbia **[61]**	Slovakia **[62]**	Czech Republic **[56]**
Hunting season	2013/2014 - 2016/2017	May 1st - January 31st in 2020 and 2021 years	2017 - 2019	December 2012 - December 2019
Hunting area	Lower Silesia, Opole, Subcarpathia	four regions of Serbia	various locations in Slovakia	Novohradské (Gratzen) Mountains
Cesium^{137}Cs (Bq/kg)	<1.18 - 11.47	0.05–0.38 Bq/ kg North Serbia, 0.21–5.18 Bq/ kg Eastern Serbia	0.40 - 37.2	981 Bq·kg^{-1} Median 358 Maximum 14252
Cesium ^{134}Cs (Bq/kg)	<1.06	0.01–0.07 Bq/ kg - North Serbia, 0.02–1.11 Bq/ kg - Eastern Serbia	nd	nd

Character-ristics	European countries Belarus **[63]**	Germany **[64]**	Italy **[65]**	Italy **[66]**
Hunting season	1991-2008	2019–2021	nd	2014and2016
Hunting area	Belarusia Polesie.	Bavaria	Reggio Calabria	Chisone/Germanasca Valley and PelliceValley districts (Piedmont)
Cesium ^{137}Cs (Bq/kg)	0.5-661 kBq/kg in the Alienation Zone, 0.3- 105 kBq/kg in the permanent control zone and 0.1-2.4 kBq/kg in the periodic control zone	0.37-14 kBq·kg$_{-1}$	0.06 - 2.14 Bq kg^{1}	2014 liver 0.0-39.7 Bq/kg; 2016 liver 3.1-113.3 Bq/kg Kidney 4.5-192.0 Bq/kg
Cesium ^{134}Cs (Bq/kg)	nd	nd	nd	nd

Note: nd - no data.

Table 6 Content of cesium ^{137}Cs and cesium ^{134}Cs in the tissues of wild boars hunted in various regions of Poland (Bq/kg fresh meat) (n= 4) **[47]**.

Characteristics	**Voivodeships** Dolnośląskie Lower Silesi n=2	Opolskie Opole n=1	Podkarpackie Subcarpathia n=1
Cesium ^{137}Cs (Bq/kg)	<1.18 - 6.73	<1.17	11.47±1.17
Cesium ^{134}Cs (Bq/kg)	<1.06	<0.97	<0.62

Chlorinated hydrocarbons content

Levels of persistent organic pollutants in wildlife reflect environmental contamination by these compounds **[47]**. Wildlife and game, especially wild boars, are good indicators of environmental contamination by chlorinated hydrocarbons, and venison is one of the main secondary sources of human contamination, hence its monitoring seems justified. The most frequently detected polychlorinated biphenyls PCB congeners were as follows: PCB 153 in 3 samples, and PCB 138, PCB 180, PCB 28, and PCB 52.

Dichlorodiphenyldichloroethylene (DDE) and p,p’- DDE were found in the adipose tissue of wild boars (Table 7). In the study by **[67]**, the average DDT concentration in the fat tissue of wild boars was 0.241 mg/kg, and PCB concentrations ranged from 0.015 mg/kg. Furthermore, in most studies, these authors found the presence of p, p'-DDE in DDT as well as PCB 153, PCB 138, and PCB 180. Kaczyński et al. **[68]**, examining pesticide residues in the meat of wild boars, roe deer, and red deer from north-eastern Poland, found 28 compounds: 5 neonicotinoids, 6 organochlorine, and 5 other insecticides, 9 fungicides, and 4 herbicides, in the range of 0.1–85.3 ng g^{-1}. The highest mean concentrations were as follows: anthraquinone (85.3 ng g^{-1}) > DDT-p,p' (4.6 ng g^{-1}) > imidacloprid (4.3 ng g^{-1}) > permethrin (3.6 ng g^{-1}) > thiacloprid (2.8 ng g^{-1}). DDT and metabolites were the most frequently detected, followed by acetamiprid, tebuconazole, clothianidin, and imidacloprid. Residues were found in all (n=42) analyzed wild boar meat samples **[68]**. Petrović et al. **[69]** found higher content of chlorinated hydrocarbons in game animals from industrial regions of Serbia. For the purposes of consumer protection, maximum limits (MRLs) for pesticide residues have been established in food of plant and animal origin in the European Parliament and of the Council Regulation (EC) No 396/2005 **[70]**. Maximum residue limits (MRLs) in meat, for pesticides they are: DDT (1 mg/kg fat), HCB (0.2 mg/kg), α-HCH (0.2 mg/kg), -HCH (0.1 mg/kg) and γ-HCH (0.02 mg/kg). The chemical pollutants that wild animals may have in their bodies are closely related to the chemical protection of the plants they eat. Considering that wild boars travel up to 100 km in search of food **[71]**, we cannot be certain what they have been eating, and without testing, we do not know whether wild boar meat is safe in terms of heavy metal content, pesticide residues or radioactive contamination. The consumption of wild boar offal, especially the liver and kidneys, should be strictly avoided due to the accumulation of heavy metals and radioactive contamination in these organs.

Table 7 Content of Polychlorinated Biphenyles Congeners (PCB) and pesticides in the fat tissue of wild boars (μg.kg^{-1} fat) (n= 12) **[47]**.

Polychlorinated Biphenyles Congeners	Found	Not found
PCB 101	0	12
PCB 118	0	12
PCB 138	1 (Lublin - 49 μg/kg fat)	11
PCB 153	3 Lublin 99.9±25.0 μg/kg fat Lublin 96.0±18.4 μg/kg fat Lower Silesia 9.5±1.4μg/kg fat	9
PCB 180	1 Lublin 112 μg/kg fat	11
PCB 28	1 Lublin 297.2±59.4 μg/kg fat	11
PCB 52	1 Lublin 300.1±39.0 μg/kg fat	11
DDE	6 (25.0 - 973.0 μg/kg fat)	6
p,p'- DDE	4 (11.5±4.1 - 107.8±38.8)	8
p,p'- DDT	1 (38.2±13.7)	11

Perfluoroalkyl acids (PFAAs) are among the leading chemical pollutants in the 21st century. PFAAs are used in the textile and paper industries and in the production of non-stick consumer goods and household products. Among them, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) are commonly detected in animal raw materials **[72]**. Wild boars are exposed to perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) originating from flora, fauna, water, and soil, and the main route of exposure to PFOA and PFOS is oral ingestion **[73]**. Wild boars accumulate PFAAs in their livers. In 2012, **[74]** found concentrations of PFOA ≤45 μg/kg and PFOS ≤1780 μg/kg in liver samples and concentrations of PFOA ≤7.4 μg/kg and PFOS ≤28.6 μg/kg in muscle tissue of wild boars in Hesse, Germany. Phthalates, or salts and esters of phthalic acid, also pose a threat to the environment and human and animal health. They are primarily used as plasticizers to provide flexibility and durability to plastics. Phthalates used in industry enter the environment and adversely affect humans and animals. Hair samples seem to be the best matrix for studies on long-term exposure to phthalates **[75]**. Agriculture is using more glyphosate. In 1994, the global agricultural use of glyphosate was 56,296 tons of active ingredient, increasing to 746,580 tons in 2014 [76], with some estimates suggesting that use will rise to 920,000 tons by 2025 **[77]**. Glyphosate is an active ingredient in most herbicides utilized for the purpose of weed control and desiccation on cereal and other grain crops, where wild boars feed **[78]**. Studies show glyphosate residues in plant and animal products consumed by humans and in human blood and urine **[79]** and **[80]**. Considering that wild boars feed in fields where glyphosate-containing plant protection products have been used, the presence of glyphosate in wild boar meat should be monitored. Cokoski et al. **[81]** believe that the biological characteristics and feeding habits of wild boar make them suitable for use as a bioindicator of environmental pollution.

Parasites

Opponents of wild boar meat consumption fear infection with *Trichinella spiralis*, which causes trichinellosis, a serious disease in humans, or with *Alaria alata*, which causes alariasis. In 2015, the European Commission implemented Regulation (EU) 2015/1375 **[82]** laying down detailed rules on official controls for *Trichinella* in meat of domestic swine, wild boar and solipeds (e.g. horses), with the aim to reduce the number of trichinosis cases in Europe. *Trichinellosis* occurs in many countries, including Poland and the regions of Srem and the river valleys of the Danube, Drina, and Kolubara in Serbia **[83]**. In the EU, Trichinella-infected pigs are mainly found in five countries (Bulgaria, Croatia, Poland, Romania, and Spain), whereas sporadic infections in animals are reported in other Member States, including Slovakia **[84]**. The percentage of infected wild boars in Poland in 2015–2019 was 0.48% **[85]**. During this period, the highest number of trichinosis infections in wild boars was recorded in the following provinces: West Pomeranian – 1.13% (in relation to the number of animals tested), Kuyavian-Pomeranian 1.09%, Świętokrzyskie – 1.06%, Greater Poland – 0.77%. The lowest infection rates were recorded in the following provinces: Lower Silesia – 0.05%, Mazovia – 0.09%, Opole – 0.14%, and Subcarpathia – 0.17%. Research conducted by Bełcik et al. **[86]** using the multiplex PCR method showed that there are four species of tapeworms in Poland: *T. spiralis*, *T. britovi*, *T. nativa*, and *T. pseudospiralis*. Mixed infestations of *T. spiralis* and *T. britovi* have also been observed. *T. pseudospiralis*, first detected in wild boars in Poland in 2012 **[87]**, is now regularly reported, although in significantly fewer cases than other species. However, this indicates the need to use the digestion method to test meat for Trichinella, as the compressor method is not particularly effective for this parasite species. In Serbia, the number of infected wild birds decreased from 2.32% in 2012 to 1.087% in 2020 **[88]**. *Alaria lata* mesocercariae are also increasingly being reported in wild boars, and alarioza is classified as a "re-emerging disease" in Europe, especially in wetlands. Bilska-Zając et al. **[29]** report an incidence rate of 4.2% in the southern Poland provinces of Małopolska and Śląsk. Study **[89]** confirmed high prevalence of the parasite among wild boars from the Eastern Lublin Province. Strokowska et al. **[90]** reported very high incidence rates of this disease in wild boars, reaching up to 65% in the Warmian-Masurian Voivodeship, which is dominated by wetlands. Furthermore, these authors believe that the occurrence and intensity of *A. alata* infestation in wild boars depend on the environment in which they live, while the sex and age of the boar do not seem to affect the occurrence or intensity of infestation. *Alaria mesocercariae* had previously been detected in the wild boar population in Serbia **[91]**. Maleševĭc et al. **[92]** reported that the prevalence of *Alaria mesocercariae* in wild boars in northern Serbia in 2013–2015 was significantly higher than in the Czech Republic, Hungary, Austria, or Croatia. Given the occurrence of *Trichinella spiralis* and *Alaria alata* infections in wild boars, it is essential to test wild boar carcasses for the presence of trichinella, preferably using the etching method, in accordance with Commission Implementing Regulation (EU) No 2015/1375 **[82]**, due to the sensitivity of the method. These measures are proving effective, as in 2022, the 28 countries of the European Union/European Economic Area (EU/EEA) reported 39 cases of trichinosis in humans, a decrease of 49% compared to 2021, and the reporting rate in the EU/EEA was 0.01 cases per 100,000 inhabitants (the highest in Latvia (0.16) and Bulgaria (0.13). In Poland, this rate has ranged from 0.01 to 0.03 in recent years (from 1 in 2022 to 13 in 2020 cases of trichinosis in humans. In Slovakia, this rate has been 0.00 for years (the last case of trichinosis in humans was recorded in 2017). The consumption of untested pork or hunted wild boar meat poses the highest risk of trichinosis infection in the EU/EEA **[84]**. Only about 40 countries worldwide do not have a problem with *Trichinella*, due to the absence of suitable hosts for the development of this microorganism. The real problem continues to affect more than 90 countries worldwide **[93]**. According to **[94]** wild boars, as natural reservoirs of *Toxoplasma gondii* and *Neospora caninum*, pose a constant threat to humans, domestic animals and livestock, and the presence of *Anaplasma phagocytophilum* transmitted by ticks can disrupt their immune system and make them more susceptible to other parasites. In the opinion of these authors, the consumption of game meat can be considered a risk factor for *Toxoplasma gondii* infection in humans. Furthermore, parasitological studies of wild boars feeding in urban and suburban areas revealed mixed infections with coccidia and gastrointestinal nematodes. In both groups of wild boars analysed, the parasites *Eimeria debliecki*, *E. suis*, *E. polita*, *E. scabra* and *Isospora suis* were found, as well as two species of nematodes, *Ascaris suum* and *Oesophagostomum dentatum* **[95]**.

Microplastics

Contamination of food, including meat and meat products, with microplastics is becoming an increasingly serious problem due to its potential impact on consumer health. Microplastics can accumulate in the human body and lead to inflammation, organ damage, and disruption of the endocrine and immune systems **[96]** and **[97]**. Studies show that microplastics are present in livestock and poultry tissues at levels that raise concerns about consumer safety (0–7700 mg/kg or 100–180,000 particles/kg) **[98]** and **[96]**. Given the change in wild boar behavior and the fact that wild boars feeding in human settlements increasingly use landfills or garbage containers and may eat plastic packaging residues, and considering that humans have no control over where wild boars feed and what they eat, the presence of microplastics in the meat of these animals should be investigated.

CONCLUSION

The continuous growth of wild boar (*Sus scrofa*) populations across Europe and the implementation of intensive culling programs have resulted in a marked increase in the availability of wild boar meat on the market. Although this meat is often perceived as a natural and organic product free from antibiotics and growth promoters, the findings of this review clearly demonstrate that its safety is strongly influenced by environmental exposure and therefore requires strict veterinary, chemical, and radiological control.

Data from numerous European studies revealed a consistent, organ-specific pattern of heavy metal accumulation in wild boars. Muscle tissue generally contained lower concentrations of toxic elements than internal organs; however, lead (Pb) emerged as the most critical contaminant in meat intended for human consumption. In muscle tissue, Pb concentrations ranged from trace levels up to extremely high values, reaching 61.3 mg/kg wet weight in Hungary and 85.76 mg/kg dry weight in Sardinia, far exceeding EU maximum permissible limits. These elevated concentrations are largely attributed to secondary contamination from lead-based ammunition rather than environmental exposure alone. Cadmium (Cd) concentrations in muscle were typically lower but still reached 2.63 mg/kg in Slovakia and 0.98 mg/kg in Romania, with values in several regions approaching or exceeding regulatory thresholds, particularly in older animals.

The kidney was unequivocally identified as the primary organ of accumulation for cadmium and mercury (Hg). Reported Cd concentrations in kidneys ranged from 0.003 mg/kg to as high as 245.5 mg/kg, with the highest values recorded in Poland. Mercury concentrations in kidneys reached up to 3.66 mg/kg, reflecting long-term environmental exposure. In many cases, these values exceeded limits established for edible offal by several orders of magnitude. The liver showed intermediate but still concerning accumulation patterns, with cadmium concentrations reaching 39.6 mg/kg in Poland and lead concentrations up to 251.19 mg/kg dry weight in Sardinia. Mercury concentrations in liver tissue generally remained lower than in kidneys but reached 0.48 mg/kg in Slovakia.

In addition to heavy metals, wild boars have been shown to accumulate radiocaesium (137Cs), with concentrations ranging from background levels to extreme values exceeding 14,000 Bq/kg, particularly in regions affected by historical radioactive fallout, such as the Novohradské Mountains. Furthermore, residues of chlorinated hydrocarbons, pesticides, per- and polyfluoroalkyl substances (PFAS), and emerging contaminants, including microplastics, were detected, reflecting omnivorous feeding behavior, extensive home ranges, and frequent foraging in agricultural, urban, and waste-affected environments.

These results demonstrate that while wild boar meat can represent a valuable and sustainable food resource, it is also characterized by a uniquely complex contamination profile. Safe consumption requires mandatory testing for Trichinella spiralis and Alaria alata, strict exclusion of offal—especially kidneys and liver—from the food chain, regular monitoring of heavy metals and radionuclides, and the reduction or elimination of lead-based ammunition. From a public health and One Health perspective, wild boar meat should be classified as a high-risk game product, and its increasing availability should be accompanied by enhanced surveillance, evidence-based regulation, and clear consumer guidance.

REFERENCES

1. Colomer, J., Massei, G., Roos, D., Rosell, C., & Rodríguez-Teijeiro, J.D. (2024). What drives wild boar density and population growth in Mediterranean environments? Science of the Total Environment, 931, 172739. https://doi.org/10.1016/j.scitotenv.2024.172739
2. Veličković, N., Ferreira, E., Djan, M. Ernst, M, Obreht Vidaković, D., Monaco, A., & Fonseca, C. (2016). Demographic history, current expansion and future management challenges of wild boar populations in the Balkans and Europe. Heredity, 117(5), 348–357. https://doi.org/10.1038/hdy.2016.53
3. Dovrat, G., Perevolotsky, A., & Ne'eman, G. (2012). Wild boars as seed dispersal agents of exotic plants from agricultural lands to conservation areas. Journal of Arid Environments, 78, 49–54. https://doi.org/10.1016/j.jaridenv.2011.11.011
4. Ballari, S.A., & Barrios-García, M.N. (2014). A review of wild boar Sus scrofa diet. Mammal Review, 44(2), 124-134. https://doi.org/10.1111/mam.12015
5. Kopij, G., & Panek, M. (2016). Effect of Winter Temperature and Maize Food Abundance on Long-Term Population Dynamics of the Wild Boar Sus scrofa. Polish Journal of Ecology, 64(3). 436-441. https://doi.org/10.3161/15052249PJE2016.64.3.013

6. Lowe, S. M., Browne, M., Boudjelas, S., & De Poorter, M. (2000). 100 of the World's Worst Invasive Alien Species: A Selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). First published as special lift-out in Aliens, vol. 12. Updated and reprinted version: November 2004. www.issg.org/booklet.pdf
7. Barrios-Garcia, M. N., & Ballari, S. A. (2012). Impact of wild boar (Sus scrofa) in its introduced and native range: A review. Biological Invasions, 14(11), 2283–2300. https://doi.org/10.1007/s10530-012-0229-6
8. Risch, D.R., Ringma, J., & Price, M.R. (2021). The global impact of wild pigs (Sus scrofa) on terrestrial biodiversity. Scientific Reportt, 11(1). https://doi.org/10.1038/s41598-021-92691-1
9. Tack, J. (2018). Wild Boar (Sus scrofa) Populations in Europe: A Scientific Review of Population Trends and Implications for Management. European Landowners' Organization, Brussels, Belgium. https://wildbeimwild.com/wp-content/uploads/2023/08/12-Tack-J-Wild-Boar-Population-Trends-in-Europe-2018.pdf
10. Massei, G., Kindberg, J., Licoppe, A., Dragan, G., Sprem, N., Kamler, J., Baubet, E., Hohmann, U., Monaco, A., Ozolins, J., Cellina, S., Podgórski, T., Fonseca, C., Markov, N., Pokorny, B., Rosell, C., & Náhlik, A. (2014). Wild boar populations up, numbers of hunters down? A review of trends and implications for Europe. Pest Management Science, 71(4), 492–500. https://doi.org/10.1002/ps.3965
11. Genov, P. V., Focardi, S., Morimando, F., Scillitani, L., & Ahmed, A. (n.d.). Ecological Impact of Wild Boar in Natural Ecosystems. In Ecology, Conservation and Management of Wild Pigs and Peccaries (pp. 404–419). Cambridge University Press. https://doi.org/10.1017/9781316941232.038
12. Ruiz-Fons, F. A. (2017). Review of the Current Status of Relevant Zoonotic Pathogens in Wild Swine (Sus scrofa) Populations: Changes Modulating the Risk of Transmission to Humans. Transboundary and Emerging Diseases, 64(1), 68-88. https://doi.org/10.1111/tbed.12369
13. Jori, F., Pleydell, D., Burnichon, E., Casal, J., & Barasona, J. (2025). Wild boar trade and African swine fever risk of introduction into new territories: A quantitative release assessment with retrospective data of wild boar shipments to France and Spain (2010-2017). One Health, 21, 101185. https://doi.org/10.1016/j.onehlt.2025.101185
14. Milićević, V., Kureljušić, B., Maksimović Zorić, J., Savić, B., Stanojević, S., & Milakara, E. (2019). First Occurence of African Swine Fever in Serbia. Acta Veterinaria, 69(4), 443-449. https://doi.org/10.2478/acve-2019-0038
15. Smolko, P., Bučko, J., Štefanec, M., Lebocký, T., Chudý, M., Janto, R., Kubek, F., & Kropil, R. (2025). Spatio-Temporal Dynamics of African Swine Fever in Free-Ranging Wild Boar (Sus scrofa): Insights from Six Years of Surveillance and Control in Slovakia. Veterinary Sciences, 12(11), 1027. https://doi.org/10.3390/vetsci12111027
16. World Animals Voice. (2021). Denmark and the "Final Solution to the Wild Boar Question". URL: https://worldanimalsvoice.com/2021/06/23/denmark-and-the-final-solution-to-the-wild-boarquestion/. Accessed 25 June 2022
17. Gočárová, M., Moravčíková, N., Molnár, L., Fik, M., & Kasarda, R. (2025). The Impact of Biometeorological, Demographic, and Ecological Factors on the Population Density of Wild Boar in Slovakia. Sustainability, 17(10), 4516. https://doi.org/10.3390/su17104516
18. Drimaj, J., Kamler, J., Plhal, R., Janata, P., Adamec, Z., & Homolka, M. (2021). Intensive hunting pressure changes local distribution of wild boar. Human-Wildlife Interactions, 15(1), 22–31. https://www.jstor.org/stable/27316245
19. Sales, J., & Kotrba, R. (2013). Meat from wild boar (Sus scrofa L.): a review. Meat Science, 94(2), 187-201. https://doi.org/10.1016/j.meatsci.2013.01.012
20. Kwiecińska, K., Kosicka-Gębska, M., Gębski, J., & Gutkowska, K. (2017). Prediction of the conditions for the consumption of game by Polish consumers. Meat Science, 131, 28-33. https://doi.org/10.1016/j.meatsci.2017.04.038
21. Tomasevic, I., Novakovic, S., Solowiej, B., Zdolec, N., Skunca, D., Krocko, M., Nedomova, S., Kolaj, R., Aleksiev, G., & Djekic, I. (2018). Consumers' perceptions, attitudes and perceived quality of game meat in ten European countries. Meat Science, 142, 5–13. https://doi.org/10.1016/j.meatsci.2018.03.016
22. Tolušić, Z., Florijančić, T., Kralik, I., Sesar, M., & Tolušić, M. (2006). Game meat market in Eastern Croatia. Poljoprivreda Journal Agriculture, 12(2), 58-63. https://hrcak.srce.hr/file/11591
23. Kilar, J., Ruda, M., & Kilar, M. 2015. Consumer interest in game (in Polish). In: Karwowska M., Gustaw W. (Eds.), Trends in human nutrition, Wyd. Nauk. PTTŻ, Krakow, Poland. https://www.up.lublin.pl/files/foodscience/sesja-pan/materialy/trendy_w_zywieniu_czlowieka.pdf

24. Batorska, M., Więcek, J., Kunowska-Slosarz, M., Puppel, K., Balcerak, M., Slosarz, J., Gołębiewski, M., Budziński, A., Kuczyńska, B., Rekiel, A., & Popczyk, B. (2016). Effect of sex on the quality of European wild boar (Sus scrofa scrofa). Annals of Warsaw University of Life Sciences-SGGW. Animal Science, 55(1), 5-11.

25. Zochowska-Kujawska, J., Lachowicz, K., Sobczak, M., Gajowiecki, L., Kotowicz, M., Zych, A., & Ortyl, B. (2010). UTILIZING MEAT FROM WILD BOARS TO PRODUCE FINELY OMMINUTED MODEL SAUSAGES WITH VARYING AMO UNTS OF ATER AND FAT ADDED. Zywnosc.Nauka.Technologia.Jakosc/Food.Science.Technology.Quality, 69(2). https://doi.org/10.15193/zntj/2010/69/029-039 (Original work published as Wykorzystanie mięsa z dzików do produkcji modelowych kiełbas drobno rozdrobnionych ze zmiennym dodatkiem wody i tłuszczu)

26. Niewiadomska, K., Kosicka-Gębska, M., Gębski, J., Gutkowska, K., Jeżewska-Zychowicz, M., & Sułek, M. (2020). Game Meat Consumption-Conscious Choice or Just a Game? Foods, 9(10), 1357. https://doi.org/10.3390/foods9101357

27. Niewiadomska, K., Kosicka-Gębska, M., Gębski, J., Jeżewska-Zychowicz, M, & Sułek, M. (2021). Perception of the Health Threats Related to the Consumption of Wild Animal Meat-Is Eating Game Risky? Foods, 10(7), 1544. https://doi.org/10.3390/foods100715444

28. Bilska-Zając, E., Różycki, M., Chmurzyńska, E., & Osek, J. (2011). Occurrence of trichinellosis in animals and humans in European Union countries and countries neighboring Poland. (In Polish). Życie Weterynaryjne, 86(4), 307-311.

29. Bilska-Zając, E., Marucci, G., Piróg-Komorowska, A., Cichocka, M., Różycki, M., Karamon, J., Sroka, J., Bełcik, A., Mizak, I., & Cencek, T. (2021). Occurrence of Alaria alata in wild boars (Sus scrofa) in Poland and detection of genetic variability between isolates. Parasitology Research, 120(1), 83-91. https://doi.org/10.1007/s00436-020-06914-x

30. Kwiecińska, K., Kosicka – Gębska, M., & Gębski, J. (2015). Safety level as a factor determining venison consumption (in Polish). Problemy Higieny i Epidemiologii, 96 (3), 594–597. http://phie.pl/pdf/phe-2015/phe-2015-3-594.pdf

31. Rudy, M. (2010). Chemical composition of wild boar meat and relationship between age and bioaccumulation of heavy metals in muscle and liver tissue. Food Additives & Contaminants: Part A, 27(4), 464-472. https://doi.org/10.1080/19440040903493785

32. Cammilleri, G., Messina, E.M.D., Pantano, L., Buscemi, M.D., Migliore, S., Blanda, V., Galluzzo, F.G., Alfano, C., Riolo, P., Lo Dico, G.M,. & Ferrantelli, V. (2025). Trace metals and metalloids in wild boars (S. scrofa) from Southern Italy: comparison between urban and wild areas. Chemosphere, 380, 144473. https://doi.org/10.1016/j.chemosphere.2025.144473

33. Bąkowska, M., Pilarczyk, B., Tomza-Marciniak, A., Pilarczyk, R., & Udała, J. (2024). Cadmium in Selected Organs of Game Animals from Areas with Different Degrees of Industrialisation and Its Intake by Human Consumers. Animals, 14(2), 305. https://doi.org/10.3390/ani14020305

34. Vidosavljević, D., Venus, M., Puntarić, D., Kalinić, L., Vidosavljević, M., Begović, M., Despot, M., & Gvozdić, V. (2025). Assessment of Selected Heavy Metals and Arsenic Concentrations in Wild Boar (Sus scrofa L.) from Papuk Nature Park (Croatia). Journal of Xenobiotics, 15(3), 74. https://doi.org/10.3390/jox15030074

35. Durkalec, M., Szkoda, J., Kolacz, R., Opaliński, S., Nawrocka, A., & Zmudzki, J. (2015). Bioaccumulation of Lead, Cadmium and Mercury in Roe Deer and Wild Boars from Areas with Different Levels of Toxic Metal Pollution. International Journal of Environmental Research, 9. 205-212. https://www.researchgate.net/publication/270339055_Bioaccumulation_of_Lead_Cadmium_and_Mercury_in_Roe_Deer_and_Wild_Boars_from_Areas_with_Different_Levels_of_Toxic_Metal_Pollution

36. Roślewska, A., Stanek, M., Janicki, B., Cygan-Szczegielniak, D., Stasiak, K., & Buzała, M. (2016). 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). Journal of Elementology, (3/2016). https://doi.org/10.5601/jelem.2015.20.2.943

37. Maľová, J., Ciberej, J., Maľa, P., Zigo, F., & Semjon, B. (2019). Heavy metal levels in the tissues of wild living animals from two distinct industrially exploited areas in Slovakia. Slovak Journal of Animal Science, 52, 100–110. https://office.sjas-journal.org/index.php/sjas/article/view/563/533

38. Gašparík, J., Binkowski, Ł.J., Jahnátek, A., Šmehýl, P., Dobiaš, M., Lukáč, N., Błaszczyk, M., Semla, M., & Massanyi, P. (2017). Levels of Metals in Kidney, Liver, and Muscle Tissue and their Influence on the Fitness for the Consumption of Wild Boar from Western Slovakia. Biological Trace Element Research, 177(2), 258-266. https://doi.org/10.1007/s12011-016-0884-z

39. Lénárt, Z., Bartha, A., Abonyi-Tóth, Z., & Lehel, J. (2023). Monitoring of metal content in the tissues of wild boar (Sus scrofa) and its food safety aspect. Environmental Science and Pollution Research, 30(6), 15899–15910 https://doi.org/10.1007/s11356-022-23329-6

40. Boișteanu, P.C., Flocea, E.I., Anchidin, B.G., Mădescu, B.M., Matei, M., Murariu, O.C., Frunză, G., Postolache, A.N., & Ciobanu, M.M. (2024). Essential and toxic elements analysis of wild boar tissues from north-eastern Romania and health risk implications. Frontiers in Sustainable Food Systems, 8. https://doi.org/10.3389/fsufs.2024.1406579

41. Bilandžić, N., Sedak, M., Đokić, M., & Šimić, N. (2010). Wild Boar Tissue Levels of Cadmium, Lead and Mercury in Seven Regions of Continental Croatia. Bulletin of Environmental Contamination and Toxicology, 84(6), 738–743. https://doi.org/10.1007/s00128-010-9999-7

42. Ertl, K., Kitzer, R., & Goessler, W. (2016). Elemental composition of game meat from Austria. Food Additives & Contaminants: Part B, 9(2), 120-126. https://doi.org/10.1080/19393210.2016.1151464

43. Danieli, P.P., Serrani, F., Primi, R., Ponzetta, M., Ronchi, B., & Amici, A. (2012). Cadmium, Lead, and Chromium in Large Game: A Local-Scale Exposure Assessment for Hunters Consuming Meat and Liver of Wild Boar. Archives of Environmental Contamination and Toxicology, 63(4), 612-627. https://doi.org/10.1007/s00244-012-9791-2

44. Palazzo, M., Tavaniello, S., Petrecca, V., Zejnelhoxha, S., Wu, M., Mucci, R., & Maiorano, G. (2021). Quality and safety of meat from wild boar hunted in Molise region. Italian Journal of Animal Science, 20(1), 1889–1898. https://doi.org/10.1080/1828051X.2021.1965924

45. Mehmood, N., Sini, M., Bocca, B., Nonnis, F., Manconi, M., Muzzeddu, M., Veneziano, V., Sgroi, G., Varcasia, A., Scala, A., Tamponi, C., & Forte, G. (2025). Lead concentrations in wild boar from Sardinia: analysis of food safety concerns. Environmental Sciences Europe, 37(1). https://doi.org/10.1186/s12302-025-01092-y

46. Demirbaş, Y., & Erduran, N. (2017). Concentration of Selected Heavy Metals in Brown Hare (Lepus europaeus) and Wild Boar (Sus Scrofa) From Central Turkey. Balkan Journal of Wildlife Research, 4(2), 26–33. https://doi.org/10.15679/bjwr.v4i2.54

47. Rutkowska-Mazur, A., Niedziółka, J., Walczycka, M., Gubała, D., Migdał, Ł., & Migdał, W. (2023). The chemical composition and safety of wild boars meat hunted in Poland. Journal of Hygienic Engineering and Design, 43, 57-69. https://keypublishing.org/jhed/wp-content/uploads/2023/08/08.-Full-paper-Alicja-Rutkowska-Mazur.pdf

48. Petrović, Z., Vranić, D., Đinović-Stojanović, J., Velebit, B., Lukić, M., & Nikolić, D. (2013). Cadmium and mercury content in liver and kidneys of wild game caught in various regions of Serbia. Lilić S., Đorđević V. (editors). Proceedings, International 57th Meat Industry Conference, Meat and Meat Products - Perspectives of Sustainable Production, Belgrade, Serbia, June 10-12, 257–262.

49. Florijančić, T., Ozimec, S., Bošković, I., Bilandžić, N., Jelkić, D., Vukšić, N., & Gross-Bošković, A. (2015). Assessment of heavy metal content in wild boar (Sus scrofa l.) hunted in eastern Croatia. Journal of Environmental Protection and Ecology, 16, 630-636.

50. Piskorová, Ľ., Vasilková, Z., & Krupicer, I. (2003). Heavy metal residues in tissues of wild boar (Sus scrofa) and red fox (Vulpes vulpes) in the Central Zemplin region of the Slovak Republic. Czech Journal of Animal Science, 48. 134-138.

51. Jota Baptista, C., Seixas, F., Gonzalo-Orden, J.M., Patinha, C., Pato, P., Ferreira da Silva, E., Merino-Goyenechea, L.J., & Oliveira, P.A. (2024). Heavy metals and metalloids in wild boars (Sus Scrofa) - a silent but serious public health hazard. Veterinary Research Communications, 48(2), 1015-1023. https://doi.org/10.1007/s11259-023-10272-1

52. Malmsten, A., Dalin, A.M., Pettersson, J., & Persson, S. (2021). Concentrations of cadmium, lead, arsenic, and some essential metals in wild boar from Sweden. European Journal of Wildlife Research, 67(2). https://doi.org/10.1007/s10344-021-01460-y

53. Cokoski, K., Beukovic, D., Maletić, V., Polovinski Horvatović, M., Tanovski, V., Vukadinović, M., Dimitrieska Stojkovikj, E., & Enimiteva, V. (2024). Occurrence of Heavy Metals (Cd, Pb, As, Hg) in the Liver of Wild Boars in the Republic of North Macedonia. Contemporary Agriculture, 73(1-2). 28-33. https://doi.org/10.2478/contagri-2024-0004

54. Hohmann, U., & Huckschlag, D. (2005). Investigations on the radiocaesium contamination of wild boar (Sus scrofa) meat in Rhineland-Palatinate: a stomach content analysis. European Journal of Wildlife Research, 51(4), 263–270. https://doi.org/10.1007/s10344-005-0108-x

55. Dvořák, P, Snášel, P, & Beňová, K. (2010). Transfer of radiocesium into wild boar meat. Acta Veterinaria Brno, 79(9), S85–S91. https://doi.org/10.2754/avb201079s9s085

56. Kouba, F., Vernerová, K., Šoch, M., Hanzal, V., Filásová, L., Semerád, Z., Svoboda, F., & Rosmus, J. (2022). Radiocaesium in wild boars in Novohradské (Gratzen) mountains. Acta Veterinaria Brno, 91(1), 87–97. https://doi.org/10.2754/avb202291010087
57. Council Regulation (EC) No 1048/2009 of 23 October 2009 amending Regulation (EC) No 733/2008 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1048
58. Ołoś, G., & Dołhańczuk-Śródka, A. (2021). Levels of 137Cs in game and soil in Opole Anomaly, Poland in 2012–2020. Ecotoxicology and Environmental Safety, 223, 112577. https://doi.org/10.1016/j.ecoenv.2021.112577
59. Vilić, M., Barisic, D., Kraljevic, P., & Lulic, S. (2005). 137Cs concentration in meat of wild boars (Sus scrofa) in Croatia a decade and half after the Chernobyl accident. Journal of Environmental Radioactivity, 81(1), 55-62. https://doi.org/10.1016/j.jenvrad.2004.12.001
60. Czerski, P., Gembal, M., & Warenik-Bany, M. (2024). Caesium-137 in the muscles of game animals in 2015-2022 - levels and time trend. Journal of Veterinary Research, 68(2), 263–270. https://doi.org/10.2478/jvetres-2024-0026
61. Vićentijević, M., Pavlović, M., Vuković, D., Živanov, D., Ajtić, J., & Mitrović, B. (2022). Radiocesium content in wild boar meat originating from Serbia. Romanian Reports in Physics. Editura Academiei Romane, 74(710), 1-8. https://rrp.nipne.ro/2022/AN74710.pdf
62. Beňová, K., Dvořák, P., Tomko, M., & Falis, M. (2016). 137Cs monitoring in the meat of wild boar population in Slovakia. Potravinarstvo Slovak Journal of Food Sciences, 10(1), 243–247. https://doi.org/10.5219/578
63. Gulakov, A.V. 2014. Accumulation and distribution of (137) Cs and (90) Sr in the body of the wild boar (Sus scrofa) found on the territory with radioactive contamination. Journal of Environmental Radioactivity, 127, 171-175. https://doi.org/10.1016/j.jenvrad.2013.06.008
64. Stäger, F., Zok, D., Schiller, A.K., Feng, B., & Steinhauser, G. (2023). Disproportionately High Contributions of 60-Year-Old Weapons-137Cs Explain the Persistence of Radioactive Contamination in Bavarian Wild Boars. Environmental science & Technology, 57(36), 13601–13611. https://doi.org/10.1021/acs.est.3c03565
65. Caridi, F., D'Agostino, M., & Belvedere, A. (2020). Radioactivity in Calabrian (Southern Italy) Wild Boar Meat. Applied Sciences, 10(10), 3580. https://doi.org/10.3390/app10103580
66. Pattono, D., Mannelli, A., Dalmasso, A., Orusa, R., Faure Ragani, M., & Bottero, M.T. (2024). 137Cesium (137Cs) assessment in wild boars from northwestern Italy. PLOS ONE, 9, 19(5), e0303093. https://doi.org/10.1371/journal.pone.0303093
67. Niewiadowska, A., Kiljanek, T., Semeniuk, S., & Żmudzki, J. (2013). Organochlorine Pesticides and Polychlorinated Biphenyls in Game Animals from Poland. Bulletin of the Veterinary Institute in Pulawy, 57(2), 197–201. https://doi.org/10.2478/bvip-2013-0036
68. Kaczyński, P., Łozowicka, B., Perkowski, M., Zoń, W., Hrynko, I., Rutkowska, E., & Skibko, Z. (2021). Impact of broad-spectrum pesticides used in the agricultural and forestry sector on the pesticide profile in wild boar, roe deer and deer and risk assessment for venison consumers. Science of the Total Environment, 784:147215. https://doi.org/10.1016/j.scitotenv.2021.147215
69. Petrović, J., Kartalović, B., Mirčeta, J., Radulović, J. P., Ratajac, R., & Mastanjević, K. (2021). Organochlorine pesticides and NDL-PCBs in wild boars from flatland region with intensive agricultural activities. Food Additives & Contaminants: Part B, 15(1), 20–30. https://doi.org/10.1080/19393210.2021.1976287
70. European Parliament and of the Council (2005). Regulation (EC) No 396/2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC. OJ L 70. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005R0396
71. Jerina, K., Pokorny, B., & Stergar, M. (2014). First evidence of long-distance dispersal of adult female wild boar (Sus scrofa) with piglets. European Journal of Wildlife Research, 60(2), 367–370. https://doi.org/10.1007/s10344-014-0796-1
72. Felder, C., Trompeter, L., Skutlarek, D., Färber, H., Mutters, N. T., & Heinemann, C. (2023). Exposure of a single wild boar population in North Rhine-Westphalia (Germany) to perfluoroalkyl acids. Environmental Science and Pollution Research, 30(6), 15575–15584. https://doi.org/10.1007/s11356-022-23086-6
73. Kowalczyk, J., Numata, J., Zimmermann, B., Klinger, R., Habedank, F., Just, P., Schafft, H., & Lahrssen-Wiederholt, M. (2018). Suitability of Wild Boar (Sus scrofa) as a Bioindicator for Environmental Pollution with Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS). Archives of

Environmental Contamination and Toxicology, 75(4), 594–606. https://doi.org/10.1007/s00244-018-0552-8
74. Stahl, T., Falk, S., Failing, K., Berger, J., Georgii, S., & Brunn, H. (2012). Perfluorooctanoic Acid and Perfluorooctane Sulfonate in Liver and Muscle Tissue from Wild Boar in Hesse, Germany. Archives of Environmental Contamination and Toxicology, 62(4), 696–703. https://doi.org/10.1007/s00244-011-9726-3
75. Gonkowski, S., Tzatzarakis, M., Vakonaki, E., Meschini, E., Könyves, L., & Rytel, L. (2024). Concentration levels of phthalate metabolites in wild boar hair samples. Scientific Reports, 14(1), 17228. https://doi.org/10.1038/s41598-024-68131-1
76. Antier, C., Kudsk, P., Reboud, X., Ulber, L., Baret, P.V., & Messéan, A. (2020). Glyphosate Use in the European Agricultural Sector and a Framework for Its Further Monitoring. Sustainability, 12(14), 5682. https://doi.org/10.3390/su12145682
77. Maggi, F., la Cecilia, D., Tang, F. H. M., & McBratney, A. (2020). The global environmental hazard of glyphosate use. Science of the Total Environment, 717, 137167. https://doi.org/10.1016/j.scitotenv.2020.137167
78. Neve, P., Matzrafi, M., Ulber, L., Baraibar, B., Beffa, R., Belvaux, X., Torra, J., Mennan, H., Ringselle, B., Salonen, J., Soukup, J., Andert, S., Dücker, R., Gonzalez, E., Hamouzova, K., Karpinski, I., Travlos, I., Vidotto, F., & Kudsk, P. (2024). Current and future glyphosate use in European agriculture. Weed Research, 64(3), 181-196. https://doi.org/10.1111/wre.12624
79. de Morais Valentim, J.M.B., Coradi, C., Viana, N.P., Fagundes, T.R., Micheletti, P.L., Gaboardi, S.C., Fadel, B., Pizzatti, L., Candiotto, L.Z.P., & Panis, C. (2024). Glyphosate as a Food Contaminant: Main Sources, Detection Levels, and Implications for Human and Public Health. Foods, 13(11), 1697. https://doi.org/10.3390/foods13111697
80. Bou-Mitri, C., Dagher, S., Makkawi, A., Khreyss, Z., & Hassan, H.F. (2025). Glyphosate in food: A narrative review. Journal of Agriculture and Food Research, 19.101643. https://doi.org/10.1016/j.jafr.2025.101643
81. Cokoski, K., Beuković, D., Maletić, V., Polovinski Horvatović, M., Vukadinović, M., Dimitrieska Stojković, E., & Enimiteva, V. (2023). The Wild Boar (Sus scrofa L.) as the Biomonitor of Cadmium and Lead Pollution in the Republic of North Macedonia. South-east European Forestry, 14(2), 235-243. https://doi.org/10.15177/seefor.23-20
82. Commission Implementing Regulation (EU) 2015/1375 of 10 August 2015 laying down specific rules on official controls for Trichinella in meat. Official Journal of the European Union, L 212/7. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R1375
83. Petrović, J., Grgic, Z., Pusic, I., & Urosevic, M. (2014). 13.Sylvatic trichinosis in the Vojvodina region (Serbia). In Trends in game meat hygiene (pp. 175–182). Brill | Wageningen Academic. https://doi.org/10.3920/9789086867905_014
84. European Centre for Disease Prevention and Control. Trichinellosis. In: ECDC. Annual epidemiological report for 2022. Stockholm: ECDC; 2024. https://www.ecdc.europa.eu/sites/default/files/documents/trichinellosis-annual-epidemiological-report-2022.pdf
85. Górski, K., Bombik, E., & Kondracki, S. (2021). Frequency analysis of changes and disease symptoms in wild boars in Poland in 2015-2019. Veterinarska stanica, 52(5), 525-534. https://doi.org/10.46419/vs.52.5.4
86. Bełcik, A., Korpysa-Dzirba, W., Bilska - Zając, E., Różycki, M., Gontarczyk, A., Kochanowski, M., Samorek-Pieróg, M., Karamon, J., & Cencek, T. (2022). Epidemiology of trichinellosis in Poland – the first half of 2022. (In Polish). Życie Weterynaryjne, 97(9), 607-610. https://www.researchgate.net/publication/363210396_Sytuacja_epidemiologiczna_wlosnicy_w_Polsce_-_I_polrocze_2022_r
87. Bilska-Zając, E., Różycki, M.T., Chmurzyńska, E., Karamon, J., Sroka, J., Antolak, E., Próchniak, M., & Cencek T. (2016). First record of wild boar infected with Trichinella pseudospiralis in Poland. Journal of Veterinary Research, 60(2), 147–152. https://doi.org/10.1515/jvetres-2016-0021
88. Vasilev, S., Mitic, I., Mirilovic, M., Plavsa, D., Milakara, E., Plavsic, B., & Sofronic-Milosavljevic, L. (2023). Trichinella infection in Serbia from 2011 to 2020: a success story in the field of One Health. Epidemiology and Infection, 151. https://doi.org/10.1017/S0950268823000109
89. Strokowska, N., Bełkot, Z., Wisniewski, J., Nowicki, M., Didkowska, A., Anusz, K., & Szkucik, K. (2021). Infestation of wild boar meat from the Eastern Lublin province with Alaria mesocercariae. Medycyna Weterynaryjna, 77(12), 588-593. https://doi.org/10.21521/mw.6596

90. Strokowska, N., Nowicki, M., Klich, D., Bełkot, Z., Wiśniewski, J., Didkowska, A., Chyla, P., & Anusz, K. (2020). The occurrence of Alaria alata mesocercariae in wild boars (Sus scrofa) in north-eastern Poland. International Journal for Parasitology: Parasites Wildlife, 12, 25-28. https://doi.org/10.1016/j.ijppaw.2020.04.006

91. Gavrilović, P., Pavlović, I., & Todorović, I. (2019). Alaria alata mesocercariae in domestic pigs and wild boars in South Banat, northern Serbia. Comparative Immunology, Microbiology & Infectious Diseases, 63, 142-144. https://doi.org/10.1016/j.cimid.2019.01.017

92. Maleševíc, M., Smulders, F. J. M., Petrović, J., Mirceta, J., & Paulsen, P. (2016). Alaria alata mesocercariae in wild boars (Sus scrofa) in northern Serbia after the flood disaster of 2014. Wiener Tierärztliche Monatsschrift– Veterinary Medicine Austria, 103, 345-349. https://www.wtm.at/explorer/WTM/Archiv/2016/WTM_1112_2016/wtm_11122016_Artikel_5_Art.1629.pdf

93. Pozio E. (2007). World distribution of Trichinella spp. infections in animals and humans. Veterinary parasitology, 149(1-2), 3–21. https://doi.org/10.1016/j.vetpar.2007.07.002

94. Reiterová, K., Špilovská, S., Blaňarová, L., Derdáková, M., Čobádiová, A., & Hisira, V. (2016). Wild boar (Sus scrofa) - reservoir host of Toxoplasma gondii, Neospora caninum and Anaplasma phagocytophilum in Slovakia. Acta Parasitologica, 61(2). https://doi.org/10.1515/ap-2016-0035

95. Pilarczyk, B., Tomza-Marciniak, A., Pilarczyk, R., Felska-Błaszczyk, L., Bąkowska, M., Udała, J., & Juszczak-Czasnojć, M. (2024). A Comparison of the Prevalence of Gastrointestinal Parasites in Wild Boar (Sus scrofa L.) Foraging in Urban and Suburban Areas. Animals, 14(3), 408. https://doi.org/10.3390/ani14030408

96. Olmo, L., & Holman, B.W.B. (2025). The sources and impact of microplastic intake on livestock and poultry performance and meat products: a review. Animal Production Science, 65(14). https://doi.org/10.1071/AN25022

97. Zajác, P., Čapla, J., & Čurlej, J. (2025). Microplastic Contamination of Food. Scifood, 19, 1-16. https://doi.org/10.5219/scifood.1.

98. Habib, R.Z., Kindi, R.A., Salem, F.A., Kittaneh, W. F., Poulose, V., Iftikhar, S.H., Mourad, A.-H.I., & Thiemann, T. (2022). Microplastic Contamination of Chicken Meat and Fish through Plastic Cutting Boards. International Journal of Environmental Research and Public Health, 19(20), 13442. https://doi.org/10.3390/ijerph192013442

Funds:

This research received no external funding.

Acknowledgments:

-

Competing Interests:

No potential conflict of interest was reported by the author(s).

Ethical Statement:

This article does not contain any studies that would require an ethical statement

AI Statement:

This article was written without the use of AI tools.

Contact Address:

Władysław Migdał
Affiliation: University of Agriculture in Krakow, Faculty of Food Technology, Department of Animal Product Technology, Balicka, 122, 31-149 Kraków, Poland,
Tel.: +48 502731885
E-mail: wladyslaw.migdal@urk.edu.pl
ORCID: https://orcid.org/0000-0001-5828-4227
Author contribution: conceptualisation, writing – original draft, writing – review & editing.

Čedomir Radović
Affiliation: Institute for Animal Husbandry, Autoput 16, P. Box 23, 11080, Belgrade-Zemun, Serbia,
Tel.: +381 11 2670 541
E-mail: cedomirradovic.izs@gmail.com
ORCID: https://orcid.org/0000-0002-1800-2448
Author contribution: conceptualisation, writing – original draft, writing – review & editing.

Vladimir Živković
Affiliation: Institute for Animal Husbandry, Autoput 16, P. Box 23, 11080, Belgrade-Zemun, Serbia,
Tel.: +381 11 2670 541
E-mail: vladimirzivkovic_87@yahoo.com
ORCID: https://orcid.org/0000-0001-8938-4677
Author contribution: conceptualisation, writing – original draft, writing – review & editing.

Łukasz Migdał
Affiliation: University of Agriculture in Kraków, Faculty of Animal Science, Department of Animal Genetics, Breeding and Ethology, al. Mickiewicza 24/28, 30-059 Kraków; Poland,
Tel.: +42 12 662 53 08
E-mail: lukasz.migdal@urk.edu.pl
ORCID: https://orcid.org/0000-0002-5270-9455
Author contribution: conceptualisation, writing – original draft, writing – review & editing.

Corresponding author: **Władysław Migdał**