



Prevalence and main factors for *Salmonella* spreading in wild boars — a risk for food safety

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ABSTRACT

Salmonella is not a priority pathogen for wild boar health. However, it poses a hazard for meat safety. This paper presents the results of our multi-year research on the prevalence and epidemiology of *Salmonella* in hunting grounds in Vojvodina, Serbia. In total, 425 wild boars (25.3% of the total population) were studied. The overall *Salmonella* prevalence in Vojvodina boars was not high (3.1%) and was quite similar to findings from Spain, Germany and Japan. However, the prevalence in some hunting grounds was very high (13.3–33.3%). The anthropogenic impact is significant, as the prevalence is statistically significantly higher in open hunting grounds where animals have contact with domestic animals and access to animal waste. The pulstotype (PFGE) profiles confirmed a link between isolates from wild pigs and domestic animals. The category of wild boars in which *Salmonella* was most commonly found was sows older than 36 months and weighing more than 75 kg, which is a direct consequence of their increased need for protein during the lactation period when they exhibit scavenging and cannibalistic behaviour.

The measures taken against *Salmonella* in hunting grounds need to incorporate biosecurity measures that prevent anthropogenic influence. The hygienic and sanitary measures for the control of caught animals should also include enhanced measures when processing risk categories.

1. Introduction

Game meat is a highly biologically valuable foodstuff. It is not consumed often in Serbia, but it is present in the population's diet. Hunting tourism has the greatest commercial importance in our hunting grounds. However, with the opening of plants for the processing and packaging of game meat and increased interest in game farming, the availability of game meat to a wide range of consumers is increasing. Wild boar meat is associated with numerous hazards, such as microbial (*Trichinella*, *Toxoplasma*, *Alaria alata*, *Salmonella*, *Campylobacter*) (Petrović *et al.*, 2018; Petrović *et al.*, 2019;

Petersen *et al.*, 2020; Castillo-Contreras *et al.*, 2022) and chemical hazards (pesticides, heavy metals) (Petrović *et al.*, 2021). Although it is considered that *Salmonella* is not a priority pathogen in wild pigs, it is certainly a relevant pathogen in the control of game meat safety. Biosecurity measures taken in the hunting grounds and proper hygiene procedures for hunted animals prevent meat contamination (Mirčeta and Petrović, 2020). Since the main source of contamination of wild boar carcasses is faeces, the study of the prevalence of *Salmonella* in hunting grounds directly indicates the risk for meat safety. Therefore, the aim of this paper was

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to present the results of the research on the prevalence and risk factors that lead to the spread of *Salmonella* in wild boars in the hunting grounds of Vojvodina.

2. *Salmonella* prevalence in Vojvodina hunting grounds

We studied wild boar carcasses during two hunting seasons in Vojvodina region (Petrović et al., 2022). The hunting grounds Vojvodina are specific in comparison with hunting grounds in mountainous regions. Vojvodina is flat, without major natural obstacles, but near the hunting grounds are human settlements having a population of domestic animals as well as industrial plants. The study included 12 hunting grounds: 10 fenced and two open hunting grounds. The total number of wild boars in all hunting estates during the two year study was estimated at 1,677, out of which 425 wild boars were examined, i.e. 25.3% of the total population. All animals were shot and sampled during official hunts

Salmonella was detected in eight hunting grounds (66.7% of the total number), with the prevalence ranging from 1.7% up to 33.3%. As can be seen in Table 1, where data from around the world are presented, the prevalence of *Salmonella* in wild pigs is highly variable and ranges from 0% (Denmark) to 43.9% (USA) (Petersen et al., 2021; Cummings et al., 2016). The low prevalence found in Serbia (3.1%) is similar to the prevalence found in Germany, 2.4% (Plaza-Rodríguez et al., 2021), in some studies from Spain (2.9%–3.1%) (Gil Molino et al., 2019; Castillo-Contreras et al., 2022), and in Japan, 5.0% (Sasaki et al., 2013).

3. Risk factors that affect the spread of *Salmonella* in hunting grounds

In the hunting grounds of Vojvodina (Petrović et al., 2022), differing prevalences of *Salmonella* were found (Table 2). In half of the hunting grounds a low prevalence was detected (1.5–3.1%). There was no *Salmonella* in four hunting grounds, while

Table 1. Prevalences and serovars of *Salmonella* in wild boar faeces (Altissimi et al., 2023)

Prevalence	Frequency	Country	Serotype	Reference
3.1%	13/425	Serbia	<i>S. Enteritidis</i> , <i>S. Infantis</i> , <i>S. Typhimurium</i>	Petrović et al., 2022
3.1%	4/130	Spain	<i>S. Typhimurium</i> , <i>S. Bardo</i> , <i>S. Enteritidis</i>	Castillo-Contreras et al., 2022
35.6%	32/90	Italy	<i>S. Abony</i> , <i>S. Newport</i> , <i>S. Agona</i> , <i>S. Derby</i> ,	Piras et al., 2021
2.4%	13/562	Germany	<i>S. Typhimurium</i> , <i>S. Enteritidis</i> , <i>S. Stanleyville</i>	Plaza-Rodríguez et al., 2021
0%	0/115	Denmark	/	Petersen et al., 2021
2.98%	25/838	Spain		Gil Molino et al., 2019
43.9%	194/442	USA	<i>S. Montevideo</i> , <i>S. Newport</i> , <i>S. Give</i>	Cummings et al., 2016
1.1%	1/88	Sweden	/	Sannö et al., 2014
5%	2/40	Japan	<i>S. Agona</i> , <i>S. Narashino</i> , <i>S. Enteritidis</i> , <i>S. Havana</i> , <i>S. Infantis</i> , <i>S. Thompson</i>	Sasaki et al., 2013
0.3%	1/333	Spain	<i>S. Bardo</i> , <i>S. Montevideo</i> , <i>S. arizonae</i> , <i>S. Typhimurium</i>	Díaz-Sánchez et al., 2013
10.8%	54/499	Italy	<i>S. Salamae</i> , <i>S. Diarizonae</i> , <i>S. Houtenae</i> , <i>S. Fischerhuette</i>	Zottola et al., 2013
24.82%	326/1313	Italy	<i>S. enterica</i> subsp. <i>enterica</i>	Navarro-Gonzalez et al., 2012
15.4%	33/214	Spain	/	Ranucci et al., 2021

Table 2. Prevalence of *Salmonella* in each hunting ground (HG) (Petrović *et al.*, 2022)

Hunting ground	No of animals in HG per year	Examined animals (% in HG)	<i>Salmonella</i> positive animals (prevalence, %)
A	180	63 (35.0)	2 (3.2)
B	160	26 (16.3)	0
C	210	59 (28.1)	1 (1.7)
D	82	12 (14.6)	4 (33.3)
E	340	66 (19.4)	1 (1.5)
F	210	57 (27.1)	1 (1.8)
G	150	48 (32.0)	1 (2.1)
H	220	26 (11.8)	0
I	55	32 (58.2)	1 (3.1)
J	20	10 (50.0)	0
K*	35	15 (21.4)	2 (13.3)
L*	15	11 (73.3)	0
TOTAL	1677	425 (25.3)	13 (3.1)

* K and L are open hunting grounds and all others are fenced areas

in two hunting grounds, a very high prevalence was established (13.3–33.3%). Similar data were reported in Spain, where *Salmonella* was found in only 12% of hunting grounds and the prevalence ranged from 5% to 33% (Díaz-Sánchez *et al.*, 2013). In our research, several epidemiologically significant characteristics of the hunting ground that had a high prevalence (hunting ground K) were observed: this hunting ground is open, i.e. the animals inside move freely to outside the area of the hunting ground; there is a human settlement (a village) in the immediate vicinity and; wild boars were found near the illegal dump.

Open hunting grounds typically have <5 animals/km² and are considered low-density hunting grounds. Statistical analysis of our data proved that the prevalence of *Salmonella* was significantly higher in the open hunting grounds compared to the fenced ones, although some authors believe that the prevalence of pathogens is higher in high-density hunting grounds (Ortega *et al.*, 2020). However, the presence of high-risk factors, such as the illegal dump where the carcasses of domestic animals are dumped as well as the entrails after home slaughter, in this case poultry, has probably led to the spread of *Salmonella* in the low-density hunting grounds.

Salmonella is most commonly found in wild sows older than 36 months and weighing more

than 75 kg, probably as the consequence of the sow behaviour that was already observed in previous studies from Vojvodina (Prodanov-Radulović *et al.*, 2020). Due to offspring and lactation, sows have a greater need for proteins, they often roam searching for food and walk long distances, and often exhibit scavenging behaviour. They feed on carcasses of deer, boars, wild birds, rats and different domestic animals, which contributes to the transmission of pathogens. Other authors also believe that older animals carry pathogens more often, primarily due to longer exposure (Closa-Sebastià *et al.*, 2011).

4. *Salmonella* epidemiology

In open hunting areas on mountains, usually lacking a relevant domestic pig population, wild boars act as a host for *Salmonella* and some other food borne pathogens (*Mycobacterium*, *Leptospira*, *Erysipelothrix*), maintaining an active infection focus and pathogen circulation (Cano-Manuel *et al.*, 2014; Prodanov-Radulović *et al.*, 2020). However, in flat geographical areas — like Vojvodina — the situation is different. The identical and highly similar pulsed-field gel electrophoresis (PFGE) profiles found in wild boars and domestic pigs and poultry indicate the existence of molecular and potential epidemiological links. Generally, wild boars could

easily came into contact with domestic animals due to the lowland nature of the Vojvodina terrain. In our studies (Petrović et al., 2019; Petrović et al., 2014), it was concluded that one zoonotic pathogen (*Trichinella spiralis*) in Vojvodina circulates from domestic pigs to wild boars and *vice versa* in the opposite direction. Our conclusions are further supported by studies on wild boars living near human settlements in Spain, where the presence of anthropogenic *Salmonella* and *Campylobacter* spp. in wild boars has been confirmed (Castillo-Contreras et al., 2022).

5. Importance for meat safety

Wild game meat hygiene is specific and differs from that of farmed animals — it primarily relies on the hunting ground management and the training and skills of hunt participants (Mirčeta and Petrović, 2020). Critical points in the hunting process and subsequent carcass processing are shooting, evisceration, skinning and cooling, whereas major sources of microbial contamination of carcasses are gut con-

tents and skin/hair of game animals (Mirčeta et al., 2017).

6. Conclusion

The overall prevalence of *Salmonella* in Vojvodina hunting grounds is not high (3.1%). However, there are hunting grounds with a very high prevalence (up to 33.3%), which is a direct consequence of anthropogenic influence. Important risk factors include the following: proximity to human settlements, proximity to farms with terrestrial domestic animals (pigs, poultry, ruminants), and illegally disposed carcasses of domestic animals and waste after home slaughter. Research also points to a high-risk category of wild boar sows older than 36 months and weighing more than 75 kg. Therefore, measures taken to control the presence of *Salmonella* in Vojvodina's hunting grounds need to include suitable biosecurity measures that prevent potential anthropogenic influence, while hygienic and sanitary measures for control of hunted animals need to incorporate better surveillance in the processing of sows.

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