12. Reduction of lead contents in game meat: results of the 'Food safety of game meat obtained through hunting' research project

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Summary

Due to its high toxicity, no safe alimentary uptake level can be defined for lead. Therefore, an effort has to be made to minimize lead intake. Game meat belongs to the foods with a comparatively high lead content. A research project was carried out to study the effect of lead-based ammunition as compared to non-lead ammunition on contamination of game (roe deer, *Capreolus capreolus* and wild boar, *Sus scrofa*) with lead. Results of the research project clearly show that lead-based hunting ammunition significantly increases the lead concentration in the game meat. The effect of the construction of lead ammunition was also studied. Unexpectedly, there was a tendency in roe deer for bonded bullets to show higher lead contamination than fragmenting bullets. No such effect was noted in wild boar. In roe deer the point of impact of the projectile appears to have an influence on the levels of lead contamination. Increased lead levels were observed when a bone hit was reported. For wild boar no significant difference in lead contamination between a bone hit or a non-bone hit was observed. Non-lead bullets in combination with suitable game meat hygienic measures can therefore be recommended to minimize the uptake of lead in order to protect the consumers.

Keywords: ammunition, human health, game meat hygiene, consumer protection

12.1 Introduction

Recent toxicological findings indicate that a minimization of lead intake via food and drinking water is necessary because of the high toxicity of lead (EFSA, 2010). Game meat is among those food items with potentially high lead contents due to the use of lead ammunition for hunting and other factors.

According to the risk assessment 'Bleibelastung von Wildbret durch Verwendung von Bleimunition bei der Jagd (Lead contamination of game by use of lead ammunition in hunting)' of the Federal Institute for Risk Assessment (BfR) of 3rd December 2010 (BfR, 2010), a health risk resulting from the lead-containing remains of ammunition in game meat is possible for 'extreme consumers' of game meat, such as hunters and their families.

In order to acquire a knowledge-based background for political decisions, the project 'Food safety of game meat obtained through hunting' (German acronym: LEMISI project) was initiated by the Federal Ministry of Food and Agriculture (BMEL) and coordinated by BfR; the Federal States involved in the project were Mecklenburg-Western Pomerania, Lower Saxony, Saxony-Anhalt, Bavaria, Hesse, North Rhine-Westphalia, Hamburg and Bremen, further project partners were food and hunting associations, respectively. The project was already described in a previous volume of this book series, 'Trends of game meat hygiene' (Gremse *et al.*, 2014).

The main objective was to understand the contribution of lead ammunition to lead content in edible parts of game meat. It was also examined whether there was a difference in lead contamination between roe deer and wild boar.

Concerning game meat hygiene, factors that may also have an influence on lead contamination such as the choice of specific types of projectiles and the effect of the projectile – depending on the point of impact – were considered as well.

More specifically, the following questions were asked:

- In the case of lead ammunition, do the projectile's constructive characteristics lead to higher contamination with lead? Here, the hypothesis is that higher levels of lead are caused by using strong fragmenting (non-bonded) bullets, as compared to bonded constructions which may result in a lower lead content in game meat.
- Is there an association of the location of the wound channel in the carcass with contamination levels? Is there an impact when the bone rather than mainly the muscle tissue is hit by the bullet?

12.2 Material and methods

12.2.1 Project design

Animal species examined comprised roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*).

Six regions within Germany were chosen, according to the lead content of the top soil. This should allow to control for lead concentrations attributable to soil lead contamination in the (statistical) analysis. For each of the three lead content levels in top soil (i.e. low lead content, medium lead content, high lead content according to a geographical map indicating lead content in top soil – Bundesanstalt für Geowissenschaften 2004: http://www.bgr.bund.de/DE/Themen/Boden/Bilder/Bod_HGW_Karte_g.html), two regions were selected.

To elucidate the input of lead through hunting, different bullet materials were used in the project: lead ammunition and non-lead ammunition. To account for the lead distribution within the animals, from each carcass, three samples were taken, i.e. haunch, saddle and marketable meat close to the wound channel (Figure 12.1). Overall, a total of 1,254 roe deer (745 lead, 509 non-lead) and 854 wild boar (514 lead, 340 non-lead) were shot, resulting in 6,324 samples.

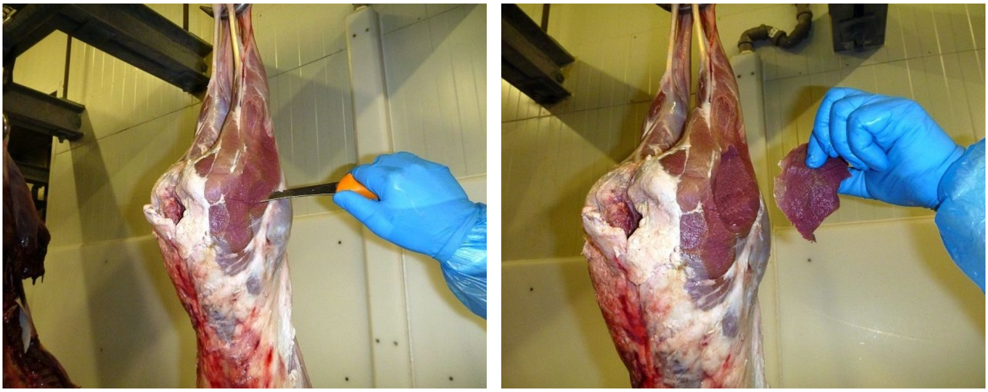

Figure 12.1. Taking a sample from the haunch (courtesy of European Poultry, Eggs and Game Association; http://www.epega.org).

12.2.2 Quality assurance

Quality assurance was a vital part of the project and quality assurance measures were integrated in all phases of the project.

12.2.3 Sampling and sample amount

Sampling was done by trained game traders. The sample amount was 100 g. Hunters had to give detailed information on how animals were killed in a specially designed data sheet (i.e. type of bullet material used, shooting distance/flight (escape) distance, location of the wound channel (entry/exit wound)) as well as to indicate the location (i.e. the site of entry/exit of the bullet) of the wound channel in a schematic drawing.

12.2.4 Statistical analysis

Beanplots were used to compare the lead content in the three edible parts of roe deer and wild boar hunted with non-lead or lead ammunition. In a beanplot, the shape is the estimated density and the short horizontal lines represent each data point. Wider lines indicate more duplicate values. The longer thick lines are the median for each sample. The plots were created with the package 'beanplot' (Kampstra, 2008) with the statistical software R version 3.2.3 (https://www.r-project.org).

The lead content of some of the samples was below the limit of detection (LOD) or the limit of quantification (LOQ); hence these are left censored data. For the descriptive beanplots, lead contents lower than the LOD or LOQ were replaced by half of the detection (or quantification) limit (middle bound).

To test significant differences in lead contents of meat according to bullet material (lead or non-lead), lead bullet construction (bonded or non-bonded), the location of wound channel (entry/exit wound) and bone hit (yes or no) and for determination of the geometric mean with 95% confidence intervals of lead content, the Tobit regression was used. Tobit regression is a statistical method for the analysis of censored data and allows consideration of different LOD's or LOQ's (Lorimer and Kiermeier, 2007). This method was executed with the function 'survreg' from the R package 'survival' (Therneau and Lumley, 2011) with the statistical software R version 3.2.3. LOD and LOQ may be specific for each laboratory and/or analysis method. To compare the lead content between different bullet constructions, different combinations of entry and exit for the wound channels (abdomen, thorax) and occurrence of a bone hit (yes or no), the geometric mean lead contents with 95% confidence intervals were presented in bar graphs created with Microsoft Excel 2010 (Microsoft, Redmond, WA, USA). The significance level was set at P=0.05.

12.3 Results and discussion

12.3.1 Distribution of the lead content in game meat

A considerable number of the samples were found to be below the detection and quantification limit. The proportions of quantifiable lead contents were between 23% (haunch; non-lead ammunition) and 61% (around the wound channel; lead ammunition) in roe deer and between 25% (haunch; non-lead ammunition) and 62% (around the wound channel; lead ammunition) in wild boar. Lead contents in game meat from roe deer and wild boar basically exhibited a big variation when lead ammunition is used (Figure 12.2 and 12.3). Sporadically, extremely high values were found around the wound channel. These parts with high contamination then pose a problem for the consumer.

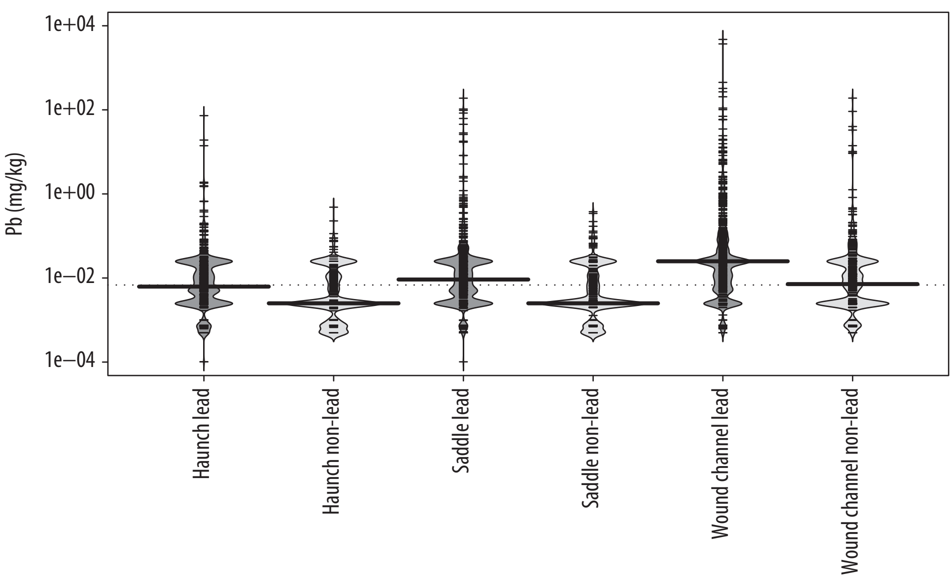

Figure 12.2. Beanplot showing lead (Pb) content in different edible parts of roe deer by bullet material (lead, non-lead).

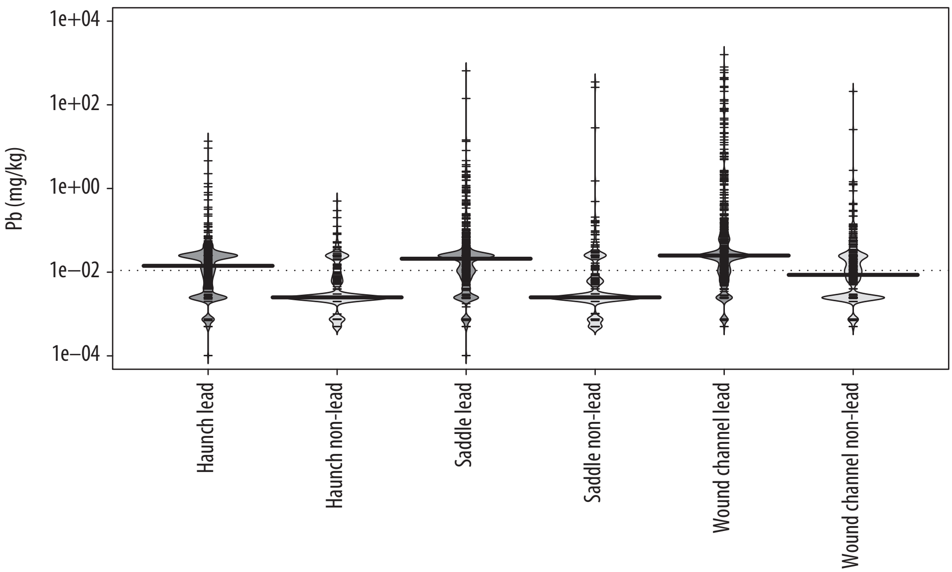

Figure 12.3. Beanplot showing lead (Pb) content in different edible parts of wild boar by bullet material (lead, non-lead).

Lead contents lower than the LOD (or LOQ) were replaced by half of the detection (or quantification) limit (middle bound). The shape of the plot represents the estimated density, short horizontal dots represent each data point. The median is indicated by a solid line for each and the overall median by a dotted line.

12.3.2 Dependence of lead content in tissues on type of ammunition used (lead vs non-lead)

The geometric mean by ammunition type and edible part was re-estimated using Tobit regression in order to account for the censored data (Table 12.1 and 12.2). In comparison to non-lead ammunition, the use of lead ammunition leads to a statistically significant increase ($P<0.001$) of the mean lead contents in all three edible parts of roe deer as well as in wild boar (Table 12.1 and 12.2).

This finding was further supported by the fact that the contamination around the wound channel was highest (Figure 12.4). This could be observed in wild boar (Figure 12.4) and roe deer (results not shown). Even though the wound channel was cut out, some lead fragments may have entered the edible section. Saddle and haunch were less contaminated, as had been expected because of the distance to the wound channel.

Even in the wild boar shot with non-lead ammunition, a certain amount of lead was found around the wound channel. This may be partly explained by the fact that even in the so called non-lead ammunition there may be some traces of lead in addition to some background

Table 12.1. Lead content in hunted roe deer (mg/kg) (LEMISI project).

Sample	Bullet	n	GM (95%-CI)[1,2]	Mean value[3]	Median[3]	Maximum
Haunch	lead	745	0.0028*** (0.0016;0.0051)	0.169	0.006	73.0
	non-lead	509	0.00074 (0.0006;0.0009)	0.010	0.003	0.48
Saddle	lead	745	0.0043*** (0.0022;0.0083)	0.968	0.009	189.29
	non-lead	509	0.00069 (0.0005;0.0009)	0.012	0.003	0.3781
Close to wound	lead	745	0.0138*** (0.0071;0.0265)	13.958	0.025	4,727.979
channel	non-lead	509	0.0027 (0.0020;0.0036)	0.807	0.007	190.4

[1] GM = geometric mean, based on Tobit model.
[2] *** = P<0.001: P-value indicates the difference between lead and non-lead per subsample.
[3] Values < limit of detection (LOD) or limit of quantification (LOQ) were set to 0.5 LOD or LOQ.

Table 12.2. Lead content in hunted wild boar (mg/kg) (LEMISI project).

Sample	Bullet	n	GM (95%-CI)[1,2]	Mean value[3]	Median[3]	Maximum
Haunch	lead	514	0.0040*** (0.0020; 0.0081)	0.086	0.014	13.517
	non-lead	340	0.0010 (0.0007; 0.0014)	0.0011	0.003	0.501
Saddle	lead	514	0.0067*** (0.0028; 0.0159)	1.716	0.021	650.100
	non-lead	340	0.0008 (0.0005; 0.0012)	1.904	0.003	351.932
Close to wound	lead	514	0.0219*** (0.0094; 0.0513)	14.302	0.025	1,582.060
channel	non-lead	340	0.0032 (0.0022; 0.0047)	0.733	0.009	209.00

[1] GM = geometric mean, based on Tobit model.
[2] *** = P<0.001: P-value indicates the difference between lead and non-lead per subsample.
[3] Values < limit of detection (LOD) or limit of quantification (LOQ) were set to 0.5 LOD or LOQ.

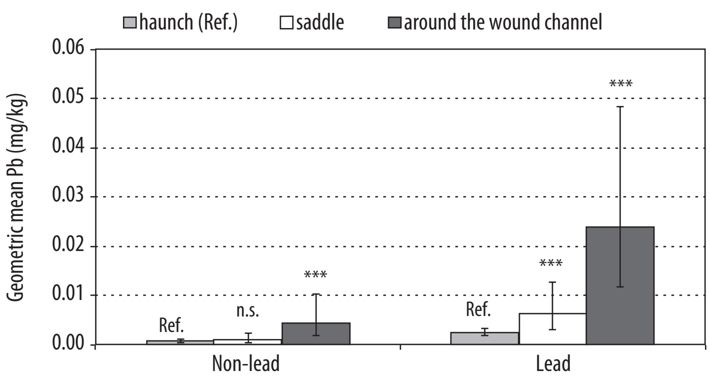

*Figure 12.4. Comparison between the three subsamples (haunch, saddle, around wound channel) using Tobit regression in wild boar. Ref. = reference category; n.s. = not significant; ***P<0.001, based on Tobit model.*

contamination. These findings were also statistically significant when taking into account the effect of regions. The effects were observed for the two species (BfR, 2014a).

12.3.3 Comparison of the game species

A comparison between the two species revealed that wild boar shows higher lead contamination than roe deer (Figure 12.5). That applied to the lead-containing bullets and all three subsamples. We hypothesize that this may be explained by the different body types of the roe deer and wild boar: roe deer has a significantly lower mean body weight than wild boar, thus the body mass of game could have impact on the target ballistic performance of a projectile, in the way that a body having a larger mass produces clearer changes in the material of the projectile compared to those with a lower mass. For roe deer with a lower body weight one would expect a smaller loss of bullet material and thus lower levels of lead as compared to wild boar. However, a detailed analysis of whether a larger/denser animal body produces clearer changes of the material of the projectile compared to a body with lower mass would include taking into account the shooting range, the type of rifle used as well as the specific construction of the projectile and some other factors. There was no difference in the lead content between the two species (for three subsamples), when hunted with non-lead bullets (results not shown).

12.3.4 Game meat hygienic aspects

12.3.4.1 Effect of bullet construction

The choice of the appropriate bullet will depend on various factors, like the type of hunting and hunted species. In addition to the emphasis on the killing potential of the bullet construction, the game meat safety aspect is another major challenge. It was expected that the use of bonded bullets – due to their construction – results in a lower contamination of meat, because these

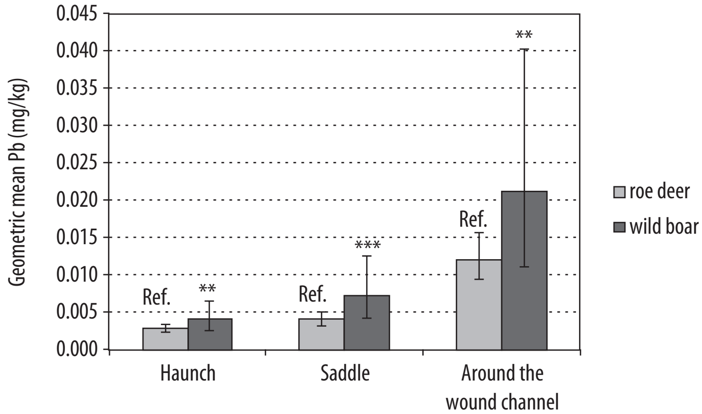

Figure 12.5. Comparison of lead (Pb) contamination of roe deer and wild boar shot with lead-containing bullets. Ref. = reference category; **P<0.05,* ****P<0.001, based on Tobit model.*

bullets are supposed to release less material to the surrounding tissue than fragmenting types. Fragmenting bullets react – by design – with heavy loss of material upon hitting the game's body and thus impart energy to the target.

Only lead containing ammunition was compared for this topic. Unexpectedly, the results showed that there was a tendency of higher lead contents in the saddle (P<0.001) and around the wound channel (P<0.05) of roe deer (Figure 12.6) when using bonded bullets (i.e. bullet types where a mass loss is not expected in the target media). These results cannot be explained at the moment. Perhaps the specific construction of the bonded bullet may play a more important role than hitherto assumed. A suitable analysis of the specific different subtypes of bonded bullets was not possible with the present data set because of the partly low and imbalanced number of the different bullet subtypes. In the edible tissues of wild boar no difference in lead content was observed between bonded and non-bonded bullets (mass loss expected in the target media). Also the observations in wild boar may partly depend on the specific type of bullet used. No differences between lead content of bonded and non-bonded ammunition constructions were observed when using non-lead ammunition (in all 3 edible parts and both species). Further research is needed on the possible effect of the different types of bullet constructions of bonded projectiles.

12.3.4.2 Location of wound channel

Here, the question was whether there was a specific effect of the entry and exit site of the bullet on lead levels. Descriptions of these sites and location of the wound channel were obtained from hunters' data sheets.

For roe deer, lower lead contents in the saddle (P<0.05) and around the wound channel (P<0.01) were observed when the wound channels were located in the abdomen, compared to entry and exit in thorax (Figure 12.7). No difference could be found for wild boar.

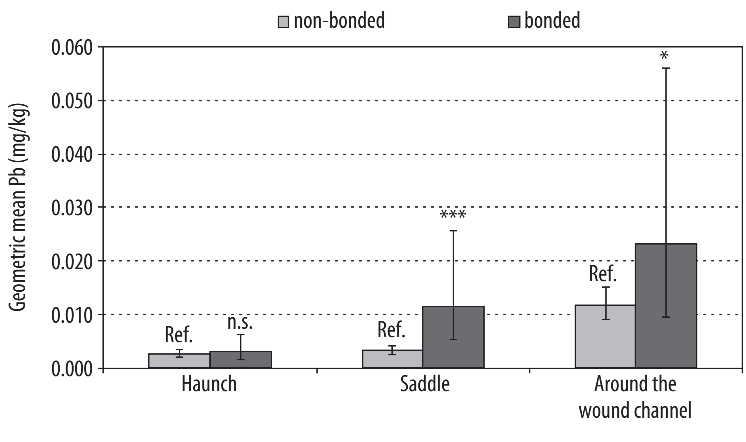

Figure 12.6. Comparison of lead (Pb) contamination of roe deer shot with bonded and non-bonded bullets. Ref. = reference category; n.s. = not significant; *P<0.05, ***P<0.001, *based on Tobit model.*

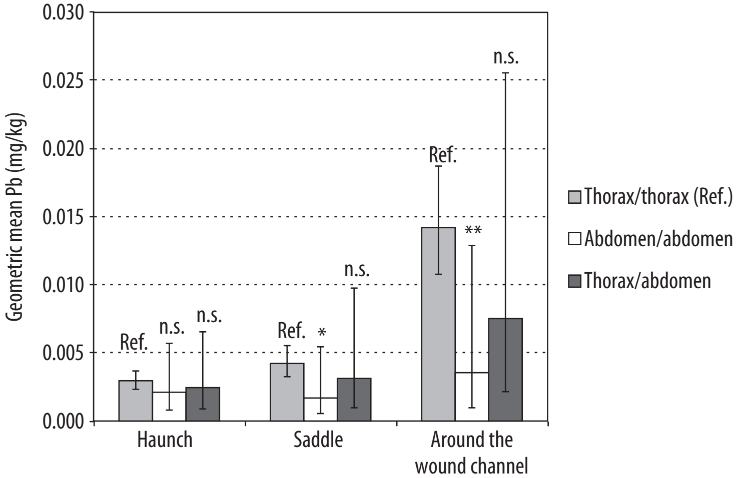

Figure 12.7. Lead (Pb) content as result of location of wound channel (entry/exit wound) and its angle (roe deer). Ref. = reference category; n.s. = not significant; *P<0.05, **P<0.01, *based on Tobit model.*

Compared to the relatively soft abdomen, the ribs of the chest provide a greater resistance when the projectile hits a bone (see also 'Effect of bone hit') and thus possible fragmentation of the bullet. This may result in the observed higher lead contents in marketable game meat from around the wound channel for roe deer hit with an entry and exit bullet in the thorax. The different build (body mass, weight, bone structure) of the wild boar compared to roe deer may offer an explanation for the different findings.

12.3.4.3 Effect of bone hit

The lead content in roe deer was also significantly increased when bones were hit (P<0.01 for all 3 subsamples; Figure 12.8). No differences could be observed for wild boar.

The density of the tissue/body mass has an effect on the loss of material from the projectile. For a bone hit the effect of body mass is less prominent. Here, the effect of a firm material such as bone has probably more of an impact. This may lead to a higher lead contamination in roe deer after bone hits, especially around the wound channel. In wild boar on the other hand, this could be less pronounced due to the larger and possibly denser body mass. Yet, there may be other factors, which could not be taken into account here, which may additionally play a role. Furthermore, there is considerable uncertainty due to reporting bias.

12.3.5 Consumer protection

The measured lead contents in edible/marketable meat of hunted game are in a similar range as the lead contents considered for the BfR risk assessment in 2010 (BfR, 2010, Table 7 p. 32). Some lead values measured close to the wound channel are on average significantly higher than values used for the 2010 exposure assessment. As pointed out here, there is also

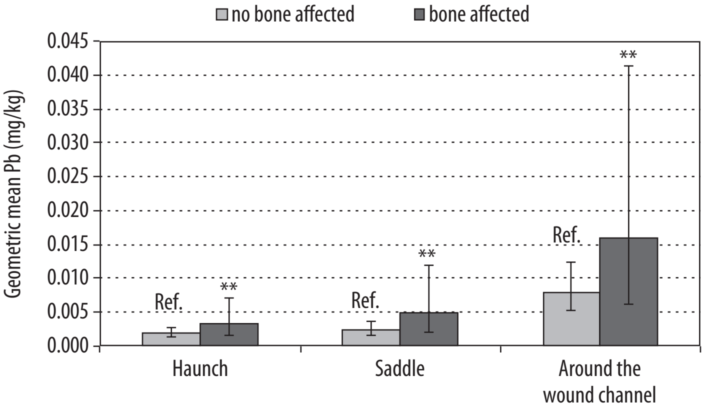

Figure 12.8. Comparison of the lead (Pb) contamination in meat of roe deer if a bone was hit or not, based on Tobit model. Ref. = reference category; n.s. = not significant; *P<0.05, **P<0.01, ***P<0.001.

a considerable heterogeneity in the amount of lead contamination, so that there is a chance that occasionally the consumer will eat game with elevated levels of lead. On the other hand quite a few samples had lead contaminations that were below the detection limit.

Since no uptake quantity of lead that can be regarded as safe to health can be established for lead, exposure to this heavy metal should be avoided to the extent that is reasonably achievable (ALARA principle). Overall, the intake of lead by all consumers via food is so high that adverse health effects are possible (BfR, 2014b). In contrast to adults, children reach or exceed already levels for developmental neurotoxicity (BfR, 2014b). Therefore, a reduction of lead intake is strongly recommended for this group. Due to its high toxicity for the developing nervous system, children, pregnant women and women of child-bearing age are advised not to consume the meat of game animals that have been shot with ammunition containing lead. For adults (excluding pregnant women and women of child-bearing age) the additional uptake of lead via average and even high consumption of game meat (women: 1 to 5 meals à 200 g per year; men: 2 to 10 meals à 200 g per year) can be neglected as compared to the lead uptake via consumption of other food groups.

For extreme consumers of game meat, i.e. consumers in hunters' households, the uptake of lead-containing hunted game meat can significantly add to the alimentary lead uptake (for this group, an average of 91 meals à 200 g per serving per year have been reported). For this group it is important to know, that different parts of the game meat show different lead concentrations and concentrations are significantly higher in meat around the wound channel, implying that in order to reduce a possible uptake of lead via consumption of game meat, different parts of the game should be consumed and different species if relevant.

12.4 Conclusions

12.4.1 What has been achieved?

The use of lead ammunition leads to statistically significant increase of mean lead contents in roe deer and wild boar meat compared to non-lead ammunition, even when effects of the region of origin were considered.

The marketable game meat around the wound channel shows on average a higher contamination than the saddle. The haunch was found to have the lowest lead values. Game meat from roe deer showed slightly lower lead levels than game meat from wild boar. Other factors such as the location of the wound channel and whether the projectile hit a bone may also have an influence. The role of the specific construction types of the bullets requires further investigation.

However, some lead content in game meat can also be due to geogenic exposure (background contamination) and alternative bullets may also contain some traces of lead. Using bullets made from alternative materials, i.e. copper and/or zinc do not appear to lead to concentrations of these elements which will present another health risk (D. Schlichting *et al*., unpublished data).

Yet, it could clearly be shown that by using non-lead ammunition, a significant reduction of the lead content in game meat is possible. Combining this with suitable game meat hygienic measures and appropriate skills of the hunters would be 'state of the art' in consumer health protection!

12.4.2 What has been neglected?

Further research is still needed to study the effect of particular bullet construction types and alternative types of bullets as well as the effect of the place of impact of the projectile. Moreover, the effect of a particular type of rifle interacting with the bullet needs to be analysed.

12.4.3 What needs to be done?

The effect of the shooting range on lead contamination and animal welfare requires to be carefully looked at. Perhaps more detailed knowledge will allow elucidating other mitigating factors for lead contamination in game meat.

In general more research on the ballistic aspects of game meat hygiene appears to be necessary. A larger societal discussion on the aspects of hunting with lead or non-lead as well as a discussion of the animal welfare aspects would support finding an acceptable solution for the majority of hunters and consumers.

Acknowledgements

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