Research project “Safety of game meat obtained through hunting” (LEMISI)

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On behalf of the Federal Ministry of Food and Agriculture (BMEL), the Federal Institute for Risk Assessment (BfR) examined the safety of game meat obtained through hunting in a research project conducted jointly with the responsible authorities of the Federal States of Saxony-Anhalt, Mecklenburg-Western Pomerania, Lower Saxony and Bavaria, as well as the German Hunting Association and Bavarian Hunting Association. The goal of this largest study undertaken in Germany to date was to determine the concentration of lead and other metals relevant to food safety, such as copper and zinc, in game meat with regard to their significance for consumer health protection. The focus was on metal concentrations resulting from the use of hunting ammunition. In essence, the objective was to establish the relevance of contaminants for human health introduced in this way.

After analysis of roe deer and wild boar samples, it was shown that hunting ammunition containing lead significantly increases the lead concentration in the game meat (around the wound channel, saddle and haunch) irrespective of the distance from the wound channel. If bullets made of alternative materials such as copper and zinc are used, contamination with these elements is only slightly increased. According to the results of the project, game meat obtained through hunting is therefore an additional source of lead uptake in humans if the game was shot with ammunition containing lead.

In an exposure estimate, the BfR came to the conclusion that, with consumption of two meals of game meat per year (normal consumers) and also of five meals a year (high consumers) with the eating habits that are customary in Germany, the additional lead uptake from the game meat is of no toxicological significance for adults. This statement does not apply to children and pregnant women. As the developing nervous system of foetuses and children shows a particularly sensitive reaction to lead, every additional uptake of lead should be avoided by these population groups.

Extreme consumers, a group which includes hunters and their families who eat up to 90 game meals per year, have to be considered separately. Game meat from animals shot with ammunition containing lead can make a considerable contribution to total uptake of this heavy metal by this group.

No uptake quantity that can be regarded as safe to health can be established for lead. Consequently, exposure to this heavy metal should be avoided to the extent that is reasonably achievable (ALARA principle). In light of the fact that lead uptake from other sources is already very high in Germany, the BfR recommends that children, pregnant women and women of child-bearing age do not consume the meat of game animals that have been shot with ammunition containing lead.

The BfR also recommends that rifle bullets that keep the transfer of lead to the meat of the animal as low as possible be used for hunting. Compared to lead ammunition, the use of low-lead alternative bullets can significantly reduce the transfer of lead to the game meat.

1. Introduction

1.1 Lead in the food chain

It has been known for a long time that the uptake of heavy metals, and in particular the uptake of lead via food intake, can influence consumers health. New toxicological findings have led to a re-assessment of the health effects of the uptake of lead. Due to these findings, a minimization of lead intake via drinking water as well as all relevant food items is necessary. Consumer exposure to lead is in general due to the intake of food with comparatively low lead content but with high consumption rates (fruit, vegetables and tap water). Other food items, which are rarely consumed by most consumers, can also make a contribution to the exposure to lead when they contain high lead contents. Game meat belongs to those food items which can contain high contents of lead due to the use of lead ammunition for hunting. According to the risk assessment "Bleibelastung von Wildbret durch Verwendung von Bleimunition bei der Jagd" of the Federal Institute for Risk Assessment (BfR) of December 3rd 2010 (BfR 2010), a health risk resulting from the lead-containing remains of ammunition in game meat is possible for certain consumer groups such as hunters and their families, if larger amounts of game meat are regularly consumed. For children up to the age of seven, as well as pregnant women, the potential health risk is higher due to the increased uptake capacity and the developmental of neurotoxicological effects of lead.

1.2 Toxicology of lead

Lead exhibits an enormous hazard potential. Already at low concentrations in the body, adverse health effects can occur. Lead accumulates in the body and bones, and can adversely affect blood formation, inner organs such as the kidneys as well as the central nervous system.
In its scientific opinion published in 2010[1], the European Food Safety Authority (EFSA) systematically evaluated new data on lead exposure of the European population and the toxicological effects of this heavy metal. Based on the model calculations done by EFSA, the panel concluded that the former PTWI (provisional tolerable weekly intake) was no longer appropriate as reference value for the health based risk assessment to ensure an adequate protection for consumers against exposure to lead via food consumption. The Federal Institute for Risk Assessment (BfR) could demonstrate - based on data from the LExUKon-project[2] - that consumers' intake of lead is primarily via the intake of staple foods. Thus, an additional regular and high consumption of game meat from animals hunted with lead ammunition could additionally lead to a marked increase in the lead uptake/burden of consumers, such that a health risk for certain consumer groups cannot be excluded.

1.3 Aim of the research project

In order to acquire a knowledge-based background for political decisions, the project „Food Safety of Game Meat Obtained through Hunting" was initiated. The lead content of the game, as well as the entry of lead in edible parts of game meat from lead-hunting ammunition was investigated, controlling for the geogenic lead contamination.

[1] http://www.efsa.europa.eu/de/efsajournal/doc/1570.pdf
[2] LExUKon-Projekt: Aufnahme von Umweltkontaminanten über Lebensmittel; (engl: foodborne exposure against environmental contaminants)
http://www.bfr.bund.de/cm/350/aufnahme_von_umweltkontaminanten_ueber_lebensmittel.pdf

The objectives of this research project and intermediate results were presented during the course of three symposia at the Federal Institute for Risk Assessment, and published in the corresponding proceedings (BfR 2012, BfR 2013, BfR 2014).[3]

2. Experimental design, implementation and statistical evaluation

In this research project, the effects of different bullet materials (lead-ammunition, non-lead ammunition) on the lead content of edible parts of game were investigated in parallel with the effects of different soil lead contents on the lead uptake of the animals via their food uptake and thus on the concentration of lead in game meat. The intention of proceeding in this way was to be able to control for the geogenic contribution of lead to game compared to the lead resulting from the use of lead-based ammunition for hunting.

For the project, regions with soil of different lead contents in Germany were identified and classified (low lead content < 30 mg lead/kg soil, medium lead content: 30 to 75 mg lead/kg soil and high lead content: > 75 mg lead/kg soil). For each lead content level two regions were selected for sampling, resulting in a total of six regions.

The animal species that were chosen comprised roe deer, wild boar and in a supplemental study red deer due to the high amount eaten/used as food. Animals were killed either with lead ammunition or specific non-lead bullets. The number of samples required was determined statistically prior to the start of the project: 120 animals per species, region and bullet type. This resulted in a total number of 4320 animals per species (i.e., for roe deer and wild boar).

Samples were taken from each hunted animal, and treated according to the principles of hygienic standards for game meat. Samples were taken from the haunch, saddle as well as meat close to the wound channel (i.e., marketable and edible meat).

Quality assurance was a vital part of the project, and quality assurance measures were integrated in all phases of the project as follows: The animals were shot by hunters who had been specifically trained as to the aims of the research project. The carcass was then brought to a game trader who also was trained as to the aims of this research project, and who carried out the sampling according to standardized specifications. The samples were then transported to the laboratories for chemical analysis, and the contents of lead, copper and zinc were determined. The analytical results were sent to the Eberswalde University for Sustainable Development (Hochschule für nachhaltige Entwicklung Eberswalde (HNEE)). There, the plausibility of sample data sheets (Probenbegleitscheine) and analytical results were determined. The approved data were afterwards sent to the German Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung; BfR) for statistical evaluation and toxicological risk assessment.

3. Results and Discussion

Lead content in game meat

[3] http://www.bfr.bund.de/cm/350/gesundheits-und-umweltaspekte-bei-der-verwendung-von-bleimunition-bei-der-jagd-tagungsband.pdf
http://www.bfr.bund.de/cm/350/alles-wild-bfr-symposium-zu-forschungsvorhaben-zum-thema-wildbret-tagungsband.pdf
http://www.bfr.bund.de/cm/343/bmel-bfr-symposium-wild-gut-erlegt-programm.pdf

The lead contents in edible parts of roe deer and wild boar (haunch, saddle and marketable meat close to the wound channel) which had been determined in the course of the LEMISI-project are presented in the following tables (Table 1 and Table 2). The results for red deer are shown in Table 3. Note that the number of samples that had originally been planned could not be reached.

Table 1: Lead content in hunted roe deer (mg/kg)
[LEMISI-project, as of October 2014]

sample	bullet	number	mean*	median*	P 90	P 95	maximum
haunch	**lead**	745	0.169	0.006	0.025	0.064	73.000
	non-lead	509	0.010	0.003	0.025	0.025	0.484
saddle	**lead**	745	0.968	0.009	0.054	0.164	189.293
	non-lead	509	0.012	0.003	0.025	0.025	0.378
close to-wound channel	**lead**	745	13.958	0.025	0.670	2.237	4727.979
	non-lead	509	0.807	0.007	0.052	0.120	190.400

*values < limit of detection or limit of quantification were set to 0.5 LOD or LOQ

Table 2: Lead content in hunted wild boar (mg/kg)
[LEMISI-project, as of October 2014]

Sample	bullet	number	mean*	median*	P 90	P 95	maximum
haunch	**lead**	514	0.086	0.014	0.040	0.067	13.517
	non-lead	340	0.0011	0.003	0.025	0.026	0.501
saddle	**lead**	514	1.716	0.021	0.102	0.691	650.100
	non-lead	340	1.904	0.003	0.025	0.052	351.932
close to-wound channel	**lead**	514	14.302	0.025	1.750	23.324	1582.060
	non-lead	340	0.733	0.009	0.056	0.127	209.000

*values < limit of detection or limit of quantification were set to 0.5 LOD or LOQ

Table 3: Lead content of hunted red deer (mg/kg)
[LEMISI-project, as of October 2014]

sample	bullet	number	mean*	median*	P 90	maximum
haunch	**lead**	64	0.014	0.010	0.030	0.090
	non-lead	26	0.023	0.016	0.058	0.120
saddle	**lead**	64	0.054	0.015	0.040	1.140
	non-lead	26	0.017	0.009	0.030	0.150
close to wound channel	**lead**	64	58.187	0.017	1.020	3442.000
	non-lead	26	0.037	0.018	0.108	0.260

*values < limit of detection or limit of quantification were set to 0.5 LOD or LOQ
The lead contents of meat of red deer are presented in a descriptive way due to the low number of samples.

The lead contents in the edible meat of hunted game obtained within the scope of the LEMI-SI-project are in a similar range to the values which had been considered for the BfR risk assessment in 2010 (BfR 2010)[4].

Significance of geogenic background contamination for the lead contents in game using lead ammunition or non-lead ammunition, respectively

In comparison to non-lead ammunition, the use of lead ammunition leads to a statistically significant increase of the mean lead contents in roe deer as well as in wild boar. These findings were also statistically significant when taking into account the effect of regions. The effects are observed in all examined meat samples, irrespective of the site of sample taking.

For red deer a similar trend of higher lead content in the meat of game which had been shot using lead ammunition was observed. However, due to the low number of samples no statistically significance can be observed for red deer.

Lead content dependent on type of ammunition used (lead - non-lead)
Lead contents in game meat basically exhibit a big variation when lead ammunition is used, in which extremely high values are sporadically found. For non-lead hunted roe deer and wild boars, lead was also detected in the edible parts. The lead contents were on average significantly lower as compared to the lead contents of game hunted with lead ammunition.

The question of the influence of the bullet construction on parameters of food safety was originally not one of the objectives of the LEMISI-project. From the data which are available to the BfR regarding the ammunition used, it can be concluded that the use of bonded lead bullets did not lead to a significantly reduced entry of lead as compared to non-bonded ammunition. Bonded bullets even caused higher entries of lead in saddle and marketable meat close to the wound channel of roe deer (see Table 4).

Table 4: Influence of bullet construction (bonded - non-bonded, respectively) on the lead content of samples of roe deer

sample	Bonded	N	coefficient	p	remarks
haunch	non-bonded (Ref.)	622			
	bonded	121	0,0558	0,599	
saddle	non-bonded (Ref.)	622			
	bonded	121	0,5472	<0,001	lead content higher if bonded bullets are used
meat close to the wound channel	non-bonded (Ref.)	622			
	bonded	121	0,297	<0,05	lead content higher if bonded bullets are used

Differences in lead contents in the three samples of meat close to the wound channel, saddle and haunch

Meat from roe deer and wild boar shot with lead ammunition taken close to the wound channel as well as from the saddle exhibited significantly higher lead contents than samples from

[4] http://www.bfr.bund.de/cm/343/bleibelastung-von-wildbret-durch-verwendung-von-bleimunition-bei-der-jagd.pdf

the haunch. Meat from areas close to the wound channel was gained according to the principles of hygiene regulations for wild game. The examined samples always complied with marketable game meat. The effects of lead ammunition on the lead content of the meat was lowest in the haunch, more pronounced in the saddle and most marked close to the wound channel. For roe deer and wild boar which had been hunted using non-lead ammunition, meat close to the wound channel exhibited higher lead contents than the haunch.

Influence of the use of non-lead ammunition on the copper and zinc content of game meat

The results do not show a consistent picture. Whereas the copper contents were somewhat higher in wild boars when non-lead ammunition was used as compared to lead ammunition, the copper contents in roe deer close to the wound channel were lower than in haunch and saddle when using non-lead or lead ammunition.

The entry of zinc by using non-lead ammunition was slightly higher in some samples as compared to lead ammunition. Copper and zinc are trace elements which are essential for humans, and the additional entry from wild game meat does not reach or exceed the toxicologically based upper levels (UL) for these metals. A risk for consumers health is not evident for the slightly increased copper and zinc levels found in game meat shot using non-lead-ammunition.

4. Evaluation/Assessment

In a general consideration of the exposure, it can be said that the mean amount of lead taken up by all consumer groups via intake of all food groups is generally so high, that adverse health effects are possible according to the assessment model of EFSA (2010).

As shown in Figure 1, toxicological reference points are already reached or exceeded, respectively, by the German population according to the exposure model of the LExUKon-project (Lebensmittelbedingte Exposition gegenüber Umweltkontaminanten; foodborne exposure against environmental contaminants) (BfR 2010b). The blood lead levels of most of the children in Germany reach or exceed the mean $BMDL_{01}$ of 12 µg/L for developmental neurotoxicity derived by EFSA in 2010 (EFSA 2010).

According to the ALARA-principle *„**A**s **L**ow **A**s **R**easonably **A**chievable“,* any additional exposure against lead should be avoided. This holds true for all population groups (men, women, children). For children up to the age of seven years and unborn children this holds especially true, since neurotoxic effects can occur which can damage the development of the nervous system. The risk assessment of BfR “Bleibelastung von Wildbret durch Verwendung von Bleimunition bei der Jagd” (BfR risk assessment Nr. 040/2011 of 3rd December 2010[5]) is still valid.

[5] http://www.bfr.bund.de/cm/343/bleibelastung-von-wildbret-durch-verwendung-von-bleimunition-bei-der-jagd.pdf

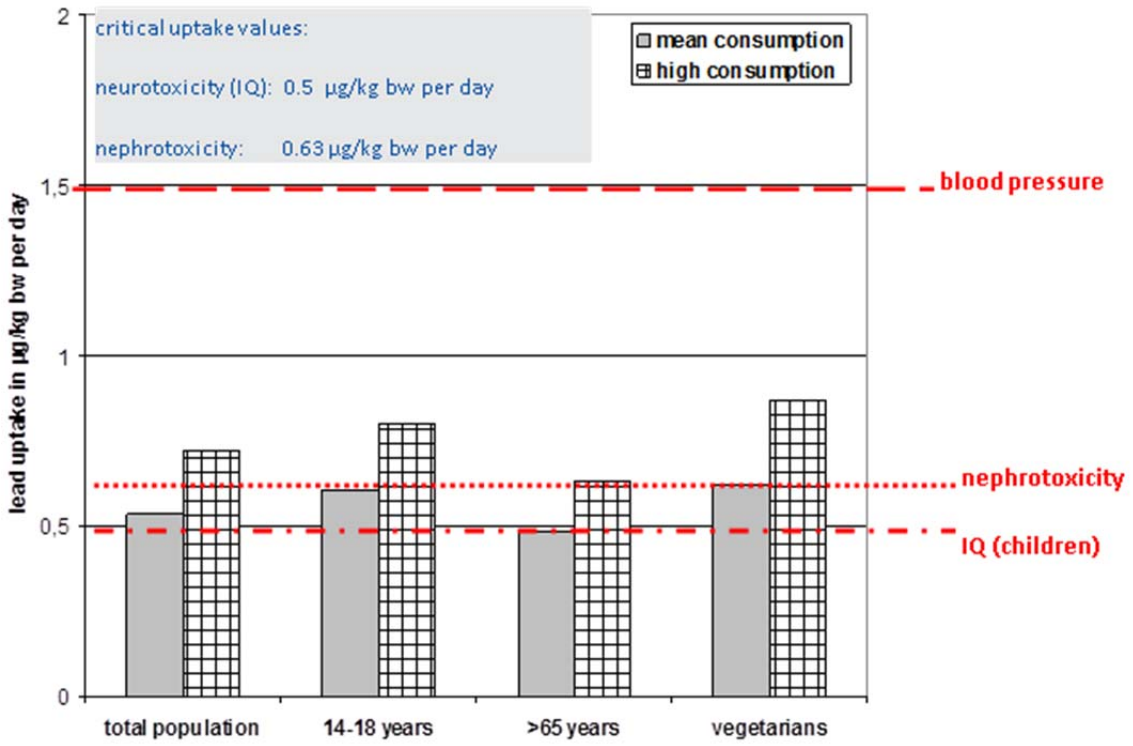

Fig 1: Lead uptake in the German population via food consumption subdivided in normal and high consumers (results from the project „LExUKon", (BfR, 2010b)*)
*) sponsored by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
In addition to children, pregnant women have been identified as a population group which is particularly sensitive to the toxicity of lead. For pregnant women this special sensitivity holds true because of the toxic effects of lead to the fetus as well as to the pregnant woman herself. During pregnancy the lead which is stored in the body is re-mobilized and contributes to the daily lead exposure via food.

Consumption of game meat – exposure via game meat consumption for consumers in Germany according to the national consumption survey II (Nationale Verzehrsstudie II; NVS II)

For the exposure assessment, the BfR differentiates between the following consumer groups (adults, meals of each 200g)

Lead intake via game meat consumption

The extent of the additional health risk through the consumption of lead-containing game meat depends directly on the lead content of the edible parts of the game meat and the consumption rate.

The lead contents which were obtained within the LEMISI-project in edible parts of hunted game were in a similar range than the values considered for the BfR risk assessment in 2010 (BfR 2010). Some values close to the wound channel were on average significantly higher than the values used in 2010 for the exposure assessment.

For adults (excluding pregnant women) with an average consumption (normal consumers) or high consumption (high consumers), the additional uptake of lead via game meat consumption is toxicologically irrelevant as compared to the total lead intake via all other food groups.

This statement does not hold true for children and pregnant women, due to the specific sensitivity of the developing nervous system against the toxic effects of lead.

Table 5: Game meat consumers: consumer groups (BfR, 2010)

consumer groups	women	men
normal consumers (mean value of consumption from NVS II)	1 meal per year	2 meals per year
high consumers (95th percentile of consumption from NVS II)	5 meals per year	10 meals per year
„extreme consumers“ (estimation and survey in hunters' households EFSA 2010; Haldiman et al., 2002)	up to 90 meals per year	

Consumers of hunters‘ households need to be considered separately due to their comparatively high consumption of game meat. For extreme consumers of game meat, the uptake of lead-containing hunted game meat can significantly add to the alimentary lead uptake.

Recommendation

The BfR recommends that particularly children up to the age of seven, pregnant women and women of childbearing age should abstain from eating game meat that has been hunted with lead ammunition due to the specific sensitivity towards the toxic effects of lead (see also: BfR risk assessment Nr. 040/2011 of 3rd December 2010).

According to the ALARA-principle, ammunition which keeps the entry of lead into the game meat as low as possible is recommended for hunting. Thereby it should be considered that in the present study the lead entry into the animals' meat could be reduced significantly when alternative non-lead bullets were used as compared to lead ammunition.

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