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Fragmentation of lead shot pellets by mincing meat for (raw) feeding to dogs

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Summary

The presence of lead particles from hunting shot or rifle bullets has been connected to elevated lead (Pb) levels in pet food from wild game. We studied whether lead fragmentation and dispersal are influenced by the mincing process. We embedded lead pellets of 2.5, 3.0 and 3.5 mm diameter in lean meat and minced it through plates with holes of 4, 5 and 8 mm diameter. We prepared six samples for each combination of pellet diameter and mincing by inserting 4 pellets per 500 g meat. We also prepared six blank samples for each pellet-plate combination.

The frequency of pellets passing the mincer without visible lesions was 13/24 to 18/24. We found damaged and halved pellets for all plate combinations. The damage was due to cutting, with parallel scratches, or breaking, with typical crystalline surface characteristic. The amount of ‘small fragments', calculated as initial weight of the embedded shot minus the weight of (intact and damaged) pellets and fragments of ≥ ½ pellet size retrieved after mincing, was in the range of 0.3–16.2 %, corresponding to 1.0–103.7 mg Pb/kg meat. We found a carry-over of pel-

Zusammenfassung

Zerkleinerung von Bleischroten während des Wolfens von Fleisch für die (Roh-) Fütterung an Hunde

Einleitung

Das Vorkommen von Bleipartikeln aus Schroten oder Büchsengeschoßen und erhöhte Bleigehalte in Heimtierfutter als Wildfleisch wurde kürzlich untersucht. Da dieses Fleisch vor der Abgabe oft gewolft wird, stellt sich die Frage, wie und ob das Wolfen Partikelgröße und -verteilung in Heimtierfutter beeinflusst.

Material und Methode

Wir untersuchten wie Bleischrote mit 2,5 3,0 und 3,5 mm Durchmesser in magerem Fleisch durch das Wolfen durch 4, 5 und 8 mm Lochscheiben beeinflusst werden. Je Schrotdurchmesser – Lochscheibenkombination wurden 6 Portionen (500 g) mit vier gewogenen, eingebetteten Schroten und nach jeder dieser Portionen eine Kontrollprobe erzeugt. Alle Portionen wurden visuell auf Schrote und große Fragmente untersucht. Die Schrote und Fragmente wurden gewogen. Bei den Untersuchungsserien mit 3,5 mm Schroten wurden zusätzlich Röntgenaufnahmen angefertigt.

Ergebnisse

Nach dem Wolfen waren, je nach Schrotdurchmesser-Lochscheiben-Kombination, 13/24–18/24 Schrote ohne sichtbare Beschädigungen. Schrote mit abgescherten Flächen und halbierte Schrote waren bei allen Schrotdurchmesser-Lochscheiben-Kombinationen nachweisbar. Die Beschädigungen waren durch Schnitte mit parallel verlaufenden Kratzern oder durch Brüche mit typischen körnigen Bruchflächen charakterisiert. Die Masse von „kleinen" Fragmenten, berechnet als Ausgangsgewicht der Schrote vor dem Wolfen abzüglich der Masse intakter und beschädigter Schrote sowie von Fragmenten ≥ ½ Schrot nach dem Wolfen betrug 0,3–16,2 %, entsprechend 1,0–103,7 mg Pb/kg Fleisch. Eine Verschleppung von Schroten und großen Fragmenten wurde in 2/6 bis 6/6 Kontrollproben beobachtet. In den Proben mit 3,5 mm Schroten wurden in den Röntgenbildern metalldichte Objekte von 1,5–1,0 und 0,1–1 mm Größe in 1/12 und 7/12 Proben (5 mm Lochscheibe) und 4/12 und 10/12 Proben (8 mm Lochscheibe) nachgewiesen. Metalldichte Verschattun-

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lets or large fragments in 2/6–6/6 blank samples, depending on pellet-plate combination. We subjected the samples with embedded 3.5 mm pellets to radiography and confirmed the presence of metal-dense objects of 1.5–1.0 and 0.1–1.0 mm size in 1/12 and 7/12 (5 mm mincing plate) and 4/12 and 10/12 (8 mm mincing plate) samples. We noted white spots < 0.1 mm diameter in every sample but did not quantify them. We conclude that the mincing process influences the integrity of lead pellets embedded in (wild game) meat, resulting not only in large fragments but also in numerous small fragments.

gen mit einem Durchmesser < 0,1 mm wurden in allen Aufnahmen gefunden, aber nicht gezählt.

Schlussfolgerung

Wir schließen aus den Ergebnissen, dass das Wolfen die Integrität von Bleischroten in (Wild-)Fleisch beeinflusst und dass nicht nur große Fragmente, sondern auch zahlreiche kleine Fragmente entstehen.

Introduction

Raw feeding of dogs is a controversial topic. Whilst raw diets may be beneficial for dogs with food intolerance, there may be health risks not only from unbalanced diets but also from biological, chemical or physical hazards (Lindinger et al. 2022). The pathogens *Salmonella* sp. and *Listeria monocytogenes* have been isolated from pet food for the raw feeding of dogs retailed in Austria (Koch et al. 2020; Lindinger et al. 2023). More recently, the presence of lead and tombac fragments from hunting ammunition in such food on the Austrian market has become a matter of concern (Paulsen et al. 2024).

Lead contamination in game meat is widely discussed and its significance for food safety has been extensively researched. There are recommendations for the risk assessment of Pb levels in foods (BfR 2010) and for assessment of the ingestion of lead-contaminated offal left in the field by birds of prey (Hunt et al. 2006). The elevated levels of lead in the blood of hunting dogs fed wild game meat (Hampton et al. 2023) were not unexpected, especially if we assume that the dogs did not receive prime cuts but rather trimmings, maybe taken from near the shot wounds. There are risks associated with feeding wild game meat contaminated with lead (particles) (Høgasen et al. 2016; Knutsen et al. 2019; Fernández et al. 2021). Even commercial pet food can have elevated lead contents or contain lead particles (Pain et al. 2023; Paulsen et al. 2024). There is a limit of 10 mg/kg (based on 88 % dry matter) for pet food in the European Union (Directive 2002/32/EC) and pet food has been recalled when Pb levels exceed this limit (Lindinger et al. 2024), although it was not specified whether this was associated with game meat. Recent studies on Pb in minced game meat destined for feeding to dogs have found various numbers and sizes of lead fragments from lead shot (Pain et al. 2023) or from rifle bullets (Paulsen et al. 2024). As the studies considered minced meat, the extent of lead dispersion and fragment sizes was presumably affected not only by fragmentation of the pellets upon impact in the wild animal´s body (Green et al. 2022) and by the selection of meat cuts for mincing but also by the mincing process itself. Pain et al. (2023) suggested that lower Pb levels in non-minced pheasant meat for human consumption than in minced pheasant meat sold as dogfood might be explained by the fragmentation of metal objects due to mincing.

We now describe and quantify the deformation and loss of mass of lead objects embedded in meat minced under semi-commercial conditions. To ensure standardized conditions, we embedded intact lead shot of 2.5, 3.0 and 3.5 mm diameter, representing common pellet sizes in hunting small wild game from pigeon to hare (Obermaier 2023). We used lean pork loin as a surrogate for pheasant or hare meat.

Materials and Methods

Preparation of meat for mincing and assembly of the grinder

We cut lean pork (loin; less than 5 % fat) into cubes of 2.5 x 2.5 x 2.5 cm and arranged the cubes to give portions of 500 g, which we stored at 3.5 °C.

We equipped the meat grinder (MaDo Primus MEW 603; Maschinenfabrik Dornhan, Dornhan, Germany) with a double-cutting system, with three plates (pre-grinder, 13 mm plate and final grinding plate) and two carriers equipped with detachable double-sided knives (System Unger, size H82). The front plate was available with 4, 5 and 8 mm hole diameter; see Figure 1. The housing of the auger was equipped with internal spiral rails of 2.5 to 3 mm height. As the auger unit had a capacity of 620 ml, we chose a similar size of meat portion, i.e. 500 g.

The final grinding plates were selected based on observations in studies on the structure of minced meat for feeding raw to dogs (Koch et al. 2020; Paulsen et al. 2024). We selected the grinding plates with hole sizes >1 mm larger than the diameter of the pellets to assure that the pellets had a chance of passing though the grinding plate without contact to the steel surfaces.

Before use and after each series of experiments, we detached the blades from their carriers and cleaned the blades, screws, carriers, perforated plates and the auger housing in a dishwasher before ultrasonicating them in distilled water (Bandelin-Sonorex, Berlin, Germany) for 15 min.

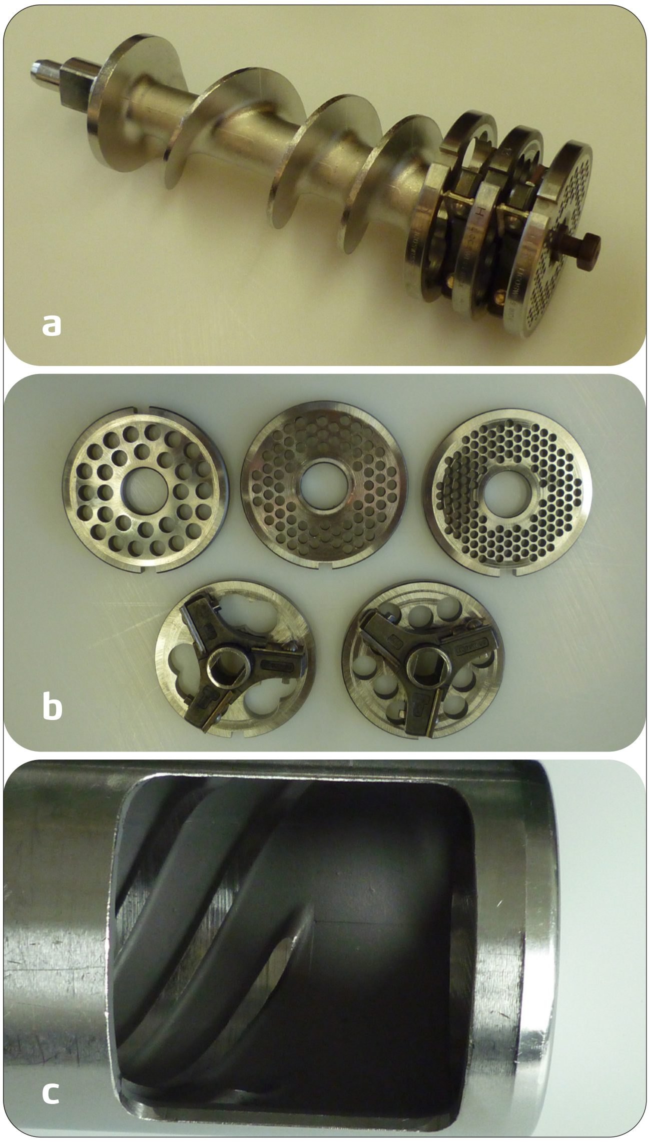

Fig. 1: (a) Assembly of the auger, plates and blades; (b) lower row: pre-grinding plate with blade carrier and 13 mm plate with blade carrier; upper row: front grinding plates with perforations of 8, 5, 4 mm diameter (from left to right); (c) view into the auger housing with internal spiral rails / (a) Zusammenstellung der Schnecke, Scheiben und Messer; (b) unten: Vorschneider mit Messeraufnahme, 13 mm Lochscheibe mit Messeraufnahme; oben: Lochscheiben mit 8, 5, 4 mm Lochdurchmesser (v.l.n.r.); (c) Blick in das Gehäuse der Förderschnecke mit den Spiralleisten

Selection of shot pellets

Lead pellets were retrieved by opening standard shotgun cartridges (Rottweil Waidmannsheil, 'Geco-X-Hartschrot'; 2.5, 3.0 and 3.5 mm; graphite-covered). We selected pellets of regular shape without scratches by microscopical examination (10 x; Bresser Analyth STR; Bresser, Rhede, Germany). Pellets with a diameter within ± 0.1 mm of the nominal diameter were selected, washed in distilled water and acetone for one minute each and allowed to dry, in order to remove the graphite coating. We formed groups of four pellets and weighed them on an analytical balance (Kern & Sohn GmbH, Balingen, Germany). We then embedded the four pellets in a 500 g portion of meat.

Embedding of the pellets into meat and mincing

To prepare the spiked portions, we selected four meat cubes from each 500 g meat portion and embedded a single pellet in each cube with the help of a toothpick. We distributed the spiked cubes evenly in the 500 g portion. Each spiked portion was minced and then a non-spiked control portion of 500 g was minced. We repeated the procedure five times, giving a total of twelve minced meat portions for each combination of pellet size and size of perforated plate. These twelve minced portions constituted a 'series'.

After mincing the last portion, we disassembled the mincer and scraped the residual meat off the blades, the holes of the perforated plates and the rails of the auger housing with toothpicks and added it to the final (control) portion. Table 1 gives the sizes of the shot pellets and the mincing plates and the numbers of portions and tests.

Retrieval of the pellets and assessment of their integrity

We spread each portion of minced meat evenly in thin layers on plastic foil and used wooden toothpicks to remove pellets and particles of lead. We removed adherent meat from the pellets and assessed their integrity microscopically. Figure 2a shows an undamaged shot, with a small indentation towards the bottom of the picture. The indentation is obviously due to the production process and exhibits the same dark grey colour as the rest of the pellet surface (Fig. 2b). We considered pellets to be damaged when they were obviously deformed or when parts of the surface had been shaved off, creating bright-grey spots.

We rinsed pellets with water, then acetone, allowed them to dry and weighed all the pellets and fragments that were not less than ½ the original size. We recorded the number of pellets with damage and calculated the weight loss per experimental series (i.e. 6 x 4 pellets).

Effect of embedding in meat and cleaning procedures on the weight of the pellets

We studied the effect of the embedding into meat and the cleaning procedure on the weight of pellets. We prepared six groups of four pellets of 3.0 mm and 3.5 mm diameter as described above and weighed

Tab. 1: Experimental series with embedded shot, sizes of shot pellets and mincing plates and numbers of samples; portions of minced meat weighed 500 g / Übersicht zu den Versuchsreihen mit eingebetteten Schroten, Schrotgrößen, Lochscheiben des Fleischwolfs und Anzahl der Portionen; die Masse der gewolften Fleischportionen betrug 500 g

Series	A	B	C	D	E	F	G
Pellet size (mm)	2.5	2.5	3.0	3.0	3.0	3.5	3.5
Diameter of holes in the mincing plate (mm)	4	5	4	5	8	5	8
Ratio pellet diameter to hole diameter	0.626	0.5	0.75	0.6	0.375	0.7	0.4375
Number of portions with embedded shot	6	6	6	6	6	6	6
Number of embedded shot pellets per portion	4	4	4	4	4	4	4
Number of controls (portions without embedded shot)	6	6	6	6	6	6	6
Examination after mincing for shot pellets or large fragments	yes	yes	yes	yes	yes	yes	yes
Examination after mincing by radiography	no	no	no	no	no	yes	yes

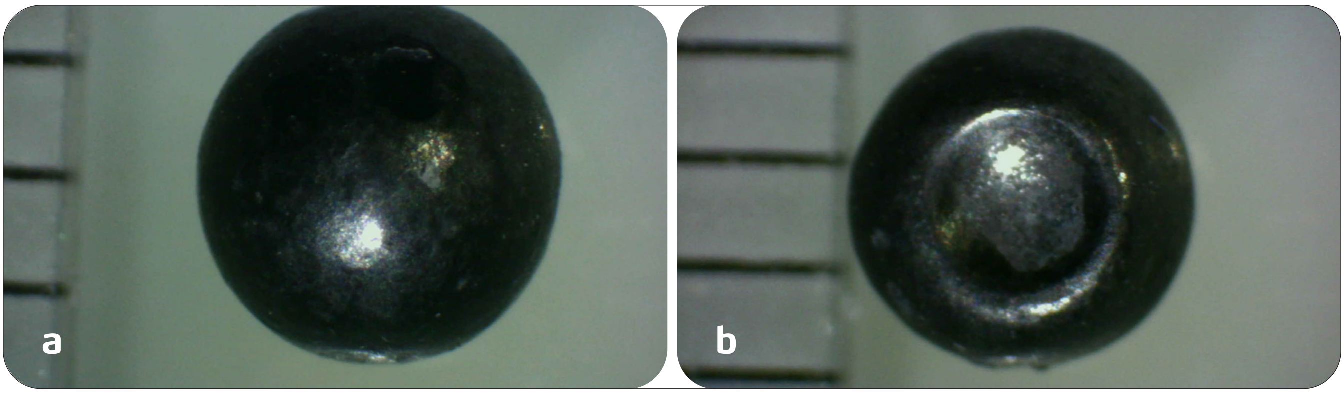

Fig. 2: (a) Undamaged shot pellet, with a small indentation towards the bottom of the picture. A mm scale to the left of the pellet; (b) Central view of the indentation. The even colour and appearance of the surface and within the indentation indicates that the indentation originated from production. A mm scale to the left of the pellet / (a) Unbeschädigtes Schrotkorn mit einer kleinen Delle am unteren Bildrand, links eine mm-Skale; (b) Blick auf die Delle. Die gleichmäßige Farbe und das Aussehen der Oberfläche zeigen, dass die Delle während der Herstellung entstanden ist. Links eine mm-Skale

them. We then embedded them in meat cubes for five minutes and removed them with toothpicks and plastic tweezers, cleaned them with toothpicks and weighed them again. We then rinsed them with distilled water for one minute, gently rubbed them with paper towels, immersed them in acetone for one minute, allowed them to dry and weighed them again in triplicate, recording the averages.

Examination of minced meat by radiography

We examined the meat from series F and G (having removed complete pellets and all fragments of ≥ ½ pellet size) by radiography (devices and settings as described by Paulsen et al. 2024) to learn whether they contained visually undetected lead fragments and, if so, of what size, shape and distribution. We placed a paperclip of 1 mm wire thickness in the periphery of the meat package to facilitate the estimation of fragment size. We also took separate pictures of a series of lead pellets with defined diameters (2.5, 3.0 and 3.5 mm with a tolerance of ± 0.05 mm) to provide a second reference for size estimation. Radiographs from previously minced pork were provided as a reference for meat with no metal-dense objects.

Three assessors examined the radiographs and gave estimates of number and size category (1 mm or more; <1 mm) of metal-dense objects. We chose the most conservative of these estimates for further analysis. Table 2 shows the sequence of preparatory procedures and examinations for each experimental series (12 portions).

Tab. 2: Sequence of preparatory procedures and examinations for each experimental series. We assessed the deformation of pellets and mass loss due to mincing, as well as carry over of lead particles from spiked sample to the subsequent control. Per series, six spiked portions and their control counterparts were tested. / Abfolge der Vorbereitungen und Untersuchungen bei jeder Versuchsreihe. Es wurden Verformung und Masseverlust der Schrote durch das Wolfen dokumentiert sowie die Verschleppung von Bleipartikeln in die Kontrollproben. Je Serie wurden sechs mit Schroten versetzte Portionen und die entsprechenden Kontrollen untersucht.

Clean and weigh 4 pellets and place 1 pellet per 2.5 cm meat cube (4 cubes per portion)	Mincing (500 g portions)	Visual check for and removal of pellets and large fragments; microscopical examination of whole pellets for damage; cleaning and weighing of pellets and large fragments and calculation of the mass of small* fragments
√	Spiked	√
	Control	√
√	Spiked	√
	Control	√
√	Spiked	√
	Control	√
√	Spiked	√
	Control	√
√	Spiked	√
	Control	√
√	Spiked	√
	Control	√

* smaller than ½ pellet

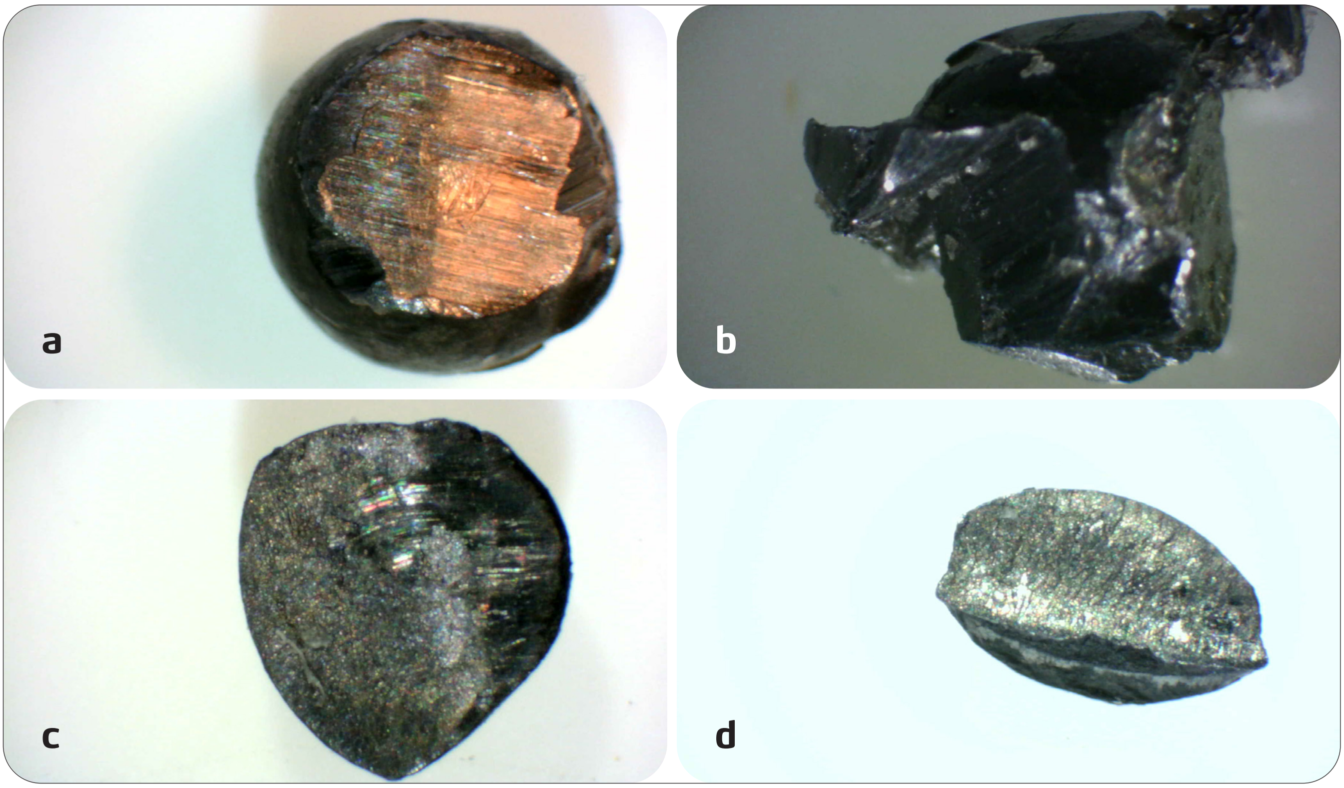

Fig. 3: (a) 3 mm diameter shot pellet, damaged during meat mincing. The flat area with the bright grey colour indicates that part of the pellet has been shaved off. (b) Shot pellet, deformed during meat mincing, with pronounced dents. (c) Halved pellet, with scratches on the right; on the left the surface is uneven after fracturing. (d) Chip of 1.5 mm length / (a) 3 mm Schrot, das während des Wolfens beschädigt wurde. Die hellgraue Fläche zeigt, dass hier ein Teil des Schrots abgeschert wurde. (b) Während des Wolfens deformiertes Schrotkorn mit deutlichen Einkerbungen. (c) Halbiertes Schrotkorn, mit Schnitt-Kratzspuren an der rechten und einer körnigen Bruchfläche an der linken Seite. (d) Chip mit 1,5 mm Länge

Results

Retrieval of intact and damaged pellets from the minced meat and loss of mass

We divided damage to the shot pellets due to mincing into four categories:

1) pellets with parts of the surface shaved off, exhibiting a surface with a bright grey metallic sheen with parallel scratches (Fig. 3a);
2) deformed pellets (Fig. 3b);
3) fragments of the shape and size of approx. ½ pellet or less, with surfaces showing shaving marks and fractures (Fig. 3c,d);
4) small particles of a few 1/10 mm dimensions; in some series, numerous small fragments and few larger fragments suggested the pellets had been completely broken down.

Occasionally pellets or large fragments were not recovered from the portion in which they had been embedded but in the subsequent control samples or even the next spiked sample. This carry-over was not unexpected as particles can be stuck between the blade-plate assembly in the mincer, especially when they are at 'the end' of the spiked portion. This does demonstrate the potential for contamination of several units within a batch with (fragments of) a single pellet. Due to the carry-over, we did not calculate the loss of mass for each of the six spiked sample-control replicates in a series but combined the findings for all twelve portions in a series. Table 3 gives the number of damaged or undamaged pellets recovered and the mass losses.

Changes in mass due to embedding and cleaning

Table 4 reports the changes in the mass of pellets after embedding into meat and cleaning. The changes in mass were in the range of 0.14 % weight loss to 0.19 % weight gain. They should be considered when interpreting the results for 2.5 mm shot in Table 3.

Radiography

We only took radiographs from portions from series F and G. These portions had been visually examined after mincing for pellets and large fragments and we took the radiographs to study the size and number of particles that had not been detected by visual examination, see Tables 5 and 6.

We identified light grey dots on all 24 radiographs but only white spots of ≥ 0.1 mm diameter were unequivocally rated as metal-dense. This is a limitation of a purely visual assessment of the radiographs. We found metal-dense areas of 1.0–1.5 mm in 1/12 portions from the 3.5 mm pellet / 5 mm mincing plate series 'F' and in 4/12 portions in the 3.5 mm pellet / 8 mm mincing plate series 'G'. The figures for metal-dense areas < 1 but > 0.1 mm were 7/12 and 10/12. The radiograph of portion 70 (Fig. 4) shows fragments of both categories.

Tab. 3: Numbers of intact or damaged pellets and large fragments after mincing (sum of the six spiked and the six control portions, corresponding to 24 pellets in 6 kg meat); numbers of portions containing pellets or large fragments; mass of the pellets embedded and mass of pellet (fragments) recovered; and mass of small fragments. / Anzahl intakter und beschädigter Schrote und großer Fragmente nach dem Wolfen (Summe der sechs mit Schrot versetzten Proben und der sechs Kontrollproben, entsprechend 24 Schroten und 6 kg Fleisch), Anzahl der Portionen mit Schroten oder großen Fragmenten; Masse der eingebetteten Schrote vor dem Wolfen und der Schrote und großen Fragmente nach dem Wolfen; Masse der kleineren Fragmente.

Series	A	B	C	D	E	F	G
Shot pellet diameter, mm	2.5	2.5	3.0	3.0	3.0	3.5	3.5
Hole diameter of mincing plate, mm	4	5	4	5	8	5	8
Microscopically intact shot pellets after mincing, n	18	18	14	17	13	13	18
Shot pellets with scraped/shaved surfaces, n	5	5	5	2	10	7	5
Fragments of ≥ ½ pellet size, n	2	2	4	4	2	5	1
Number of minced spiked portions with pellets or large fragments, n	6	6	6	6	6	6	6
Number of minced control portions with pellets or large fragments, n	5	3	2	6	3	4	3
Mass of the 24 pellets, g	2.068	2.063	3.899	3.846	3.891	5.413	5.400
Mass of recovered pellets and fragments of ≥ ½ pellet size, g	2.062	2.052	3.343	3.224	3.761	5.257	5.153
Mass of small* fragments, %	0.3	0.5	13.3	16.2	5.7	2.9	4.6
Mass of small fragments as mg Pb per kg meat	1.0	1.8	92.7	103.7	36.7	26.1	41.1

* smaller than ½ pellet

Tab. 4: Changes in mass of pellets after embedding into meat and after cleaning (6 groups of four shot pellets) / Massenänderungen der Schrote nach Einbettung in Fleisch und Reinigung (6 Gruppen zu je 4 Schroten)

Pellet diameter, mm	Mass before embedding*, g	Mass after embedding*, g	Mass after embedding and cleaning in water/acetone*, g	Mass change after embedding, %	Mass change after embedding and cleaning, %
3.0	0.3800 ± 0.000	0.3799 ± 0.001	0.3797 ± 0.001	-0.02	-0.07
3.0	0.3840 ± 0.000	0.3840 ± 0.001	0.3829 ± 0.000	0.00	-0.03
3.0	0.3850 ± 0.000	0.3859 ± 0.001	0.3857 ± 0.001	+0.22	+0.19
3.0	0.3860 ± 0.000	0.3856 ± 0.001	0.3855 ± 0.001	-0.11	-0.14
3.0	0.3720 ± 0.000	0.3725 ± 0.003	0.3722 ± 0.000	+0.13	+0.05
3.0	0.3950 ± 0.000	0.3945 ± 0.001	0.3944 ± 0.002	-0.15	-0.14
3.5	0.6290 ± 0.000	0.6283 ± 0.001	0.6283 ± 0.001	-0.11	-0.12
3.5	0.6300 ± 0.000	0.6305 ± 0.000	0.6304 ± 0.001	+0.08	+0.06
3.5	0.6760 ± 0.000	0.6763 ± 0.002	0.6765 ± 0.001	+0.04	+0.07
3.5	0.6300 ± 0.000	0.6301 ± 0.001	0.6299 ± 0.002	+0.01	-0.02
3.5	0.6430 ± 0.000	0.6431 ± 0.001	0.6429 ± 0.001	+0.01	-0.02
3.5	0.6690 ± 0.000	0.6688 ± 0.000	0.6688 ± 0.001	-0.03	-0.03

* For four pellets; each line represents a measurement in triplicate with arithmetic mean ± standard deviation; note that a plus sign indicates a gain in weight.

Tab. 5: Number of metal-dense particles on the radiographs of series F (3.5 mm pellets and 5 mm mincing plate) / Anzahl metalldichter Partikel in den Röntgenbildern der Serie F (3,5 mm Schrote und 5 mm Lochscheibe)

Portion number	51	52	53	54	55	56	57	58	59	60	61	62
Spiked (S) or blank (B)	S	B	S	B	S	B	S	B	S	B	S	B
Number of metal-dense objects 1.5–1 mm diameter on radiograph	0	0	0	0	0	0	0	0	0	1	0	0
Number of metal-dense objects < 1 and > 0.1 mm diameter on radiograph	0	0	1	0	0	0	3	12	9	16	15	13
Light-grey dots < 0.1 mm visible?	+	+	+	+	+	+	+	+	+	+	+	+

Tab. 6: Number of metal-dense particles on the radiographs of series G (3.5 mm pellets and 8 mm mincing plate) / Anzahl metalldichter Partikel in den Röntgenbildern der Serie G (3,5 mm Schrote und 8 mm Lochscheibe)

Portion number	63	64	65	66	67	68	69	70	71	72	73	74
Spiked (S) or blank (B)	S	B	S	B	S	B	S	B	S	B	S	B
Number of metal-dense objects 1.5–1 mm diameter on radiograph	1	3	0	1	0	0	0	2	0	0	0	0
Number of metal-dense objects < 1 and > 0.1 mm diameter on radiograph	6	21	1	17	3	13	12	16	2	0	0	4
Light-grey dots < 0.1 mm visible?	+	+	+	+	+	+	+	+	+	+	+	+

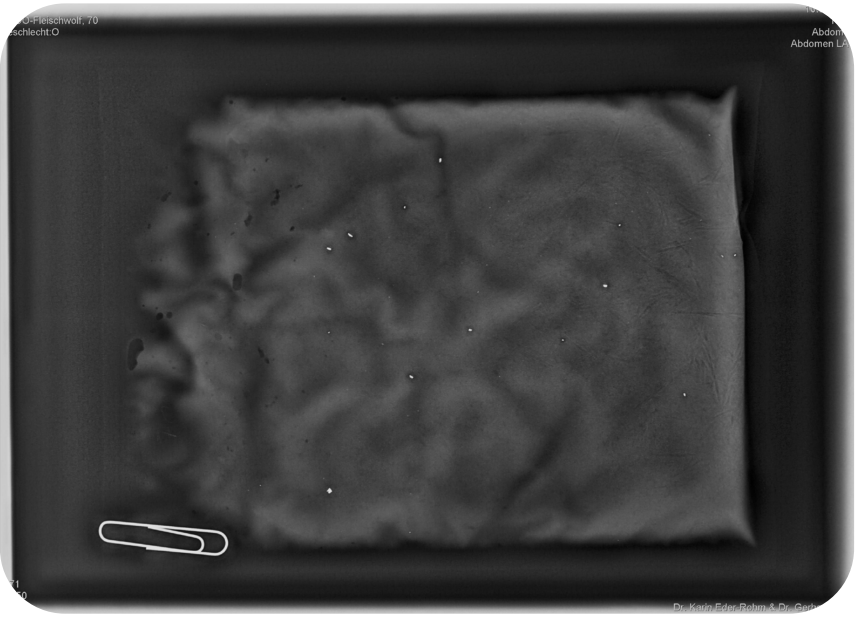

Fig. 4: Sample radiograph (portion 70, blank portion). Although the sample is blank, it contains metal-dense objects, indicating a carry-over from the previous spiked sample(s). The paperclip is made of 1 mm wire. / Beispielhaft das Röntgenbild der Portion 70 (Kontrolle). Obwohl es sich um eine Kontrollprobe handelt, sind metalldichte Objekte zu erkennen, was auf eine Verschleppung von der/den vorherigen mit Schroten versetzten Proben hindeutet. Die Büroklammer ist aus 1 mm starkem Draht gebogen.

Discussion

Damage to the lead pellets due to the mincing process

The surfaces of damaged pellets and fragments showed signs of plastic deformation and of brittleness. We saw parallel scratches on the shaved surfaces, caused either by small indentations in the cutting edges of the blades of the mincer or by the uneven surfaces of the rails and of the edge of the auger, which could damage a shot trapped between the auger and the rails of its housing. Crystalline surfaces were indicative of fractures. We have not studied whether shot pellets that penetrate animal tissues or hit bones are also fractured or whether plastic deformation dominates.

The experimental design included a particular assembly of mincing blades and perforated plates. The use of two carriers with double-sided blades can result in more intense fragmentation of pellets than when an assembly with a single blade carrier and two plates instead of three is used. This, together with the use of detachable blades (system 'Unger') instead of fixed carrier-blade units (system 'Enterprise') and the spiral rails in the auger housing, could contribute to the retention of meat particles and shot (fragments).

The combination of 3 mm pellets and plates with 4 mm or 5 mm holes gave the highest percentage of small fragments, while the 2.5 mm shot was barely affected by mincing. Considering the height of the rails (2.5–3 mm), it is conceivable that the pellets were more affected when they were trapped between the auger and the rails than they were by the knife-blade unit.

Due to the production of (small) fragments, the total surface of fragments and more or less intact pellets is greater than the surfaces of the intact pellets. This can be relevant for toxicological assessments, as a greater surface allows an increased release of Pb under conditions of gastric digestion, resulting in increased bioavailability of Pb.

The changes in mass due to embedding and cleaning of pellets (0.14 % loss to 0.19 % gain) could be due to incomplete removal of adherent meat (weight gain) or to graphite residues that were not removed by the cleaning procedure before embedding the pellets. Cleaning the pellets by ultrasonication might have been more effective. However, the same cleaning procedure was applied to the pellets retrieved after mincing and we could not exclude the possibility that ultrasonication might break chips off the pellet fragments.

Based on the mass loss or gain during cleaning, the loss of 0.3–0.5 % of mass of the 2.5 mm pellets should be interpreted with caution. Further studies are required to assess whether these small pellets tend to behave differently than thicker and heavier pellets.

We expected that the ratio of pellet-to-hole diameter would affect fragmentation but the data in Tables 1 and 2 are inconclusive. For example, the ratio was 0.625 for the 2.5 mm pellet / 4 mm plate combination and 0.6 for the 3.0 mm pellet / 4 mm plate combination, with 0.3 and 16.2 % of small particles.

Whole shot has been reported in minced pheasant meat intended for raw-feeding to dogs (Pain et al. 2023), with a mean number of 1.91 per portion and average numbers of 0.4 for fragments ≥ 0.5 mm diameter and 2.78 for smaller, yet visible fragments. The authors found no whole shot but small fragments in processed (dried or canned) dogfood from pheasant meat, so we can speculate whether the meat used to manufacture processed petfood undergoes thorough testing, e.g. with a metal detector, or whether the processing steps cause a more intensive destruction of the pellets than mincing alone would.

Carry-over of pellets and fragments

We saw a carry-over of fragments to blank samples in 2/6–6/6 control portions. Retention of shot (fragments) could be due to the blade - mincing plate configuration or the design of the auger and its housing. We will consider this point in further studies.

Limitations of this study

Our work relates to a specific mincing assembly. Although we considered different pellet diameters and mincing plate diameters, different arrangements of blades and plates may give different results. We chose a simple way to assess fragmentation and to calculate the mass of Pb in small fragments after mincing. We applied radiography to only few samples and only in a single dimension, which allows no estimate of volume, which would be possible to some extent with radiographs in two dimensions (Pain et al. 2023) or with more advanced imaging methods (Green et al. 2022). Although metal particles can be readily identified in X rays (Green et al. 2022), the identification of very small particles may be difficult. Another option is the pre-digestion of large sample volumes, e.g. in commercial enzyme-detergent combinations, followed by determination of Pb content by wet ashing and ICP-OES analysis (Green et al. 2022). As we used artificially contaminated samples, we considered a combination of visual inspection and weighing of the pellets to be sufficient, although digestion followed by Pb determination could have been helpful to quantify the carry-over of Pb (particles) from spiked samples to blanks. Despite these limitations, the microscopical inspection of pellets after mincing showed that 25–46 % of the pellets were damaged to a various extent during mincing.

Fazit für die Praxis:
Bleipartikel in Heimtierfutter mit oder aus Wildfleisch stellen eine Kontamination dar, die vom Futtermittelunternehmer beachtet werden muss. Neben der Fragmentierung von Büchsengeschossen oder von Bleischroten im Zuge der Erlegung kann auch das Wolfen des Fleisches zur Bildung von Fragmenten beitragen. Für Bleischrote konnte gezeigt werden, dass, je nach Schrotdurchmesser und Lochdurchmesser der Lochscheiben, 25–46 % der Schrote durch das Wolfen beschädigt wurden. Damit wird aus einer lokalisierten eine zwar noch immer inhomogene, aber disseminierte und schwer beherrschbare Kontamination. Nachdem über die Fragmentierung die Gesamtoberfläche der Bleipartikel steigt, ist auch von einer erhöhten Bioverfügbarkeit auszugehen. Obwohl die Möglichkeit der Fragmentierung auch für Schrote aus anderen Materialien als Blei besteht, würde der Verzicht auf die Verwendung bleihaltiger Schrote zumindest aus toxikologischer Sicht die Vermeidung einer chemischen Gefahr darstellen und könnte zur Futtermittelsicherheit beitragen.

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