Impact of selenium toxicity on livestock health, fitness for export and pasture management: a case study

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Abstract

In July 2021, an excessive application of sodium selenate to pasture resulted in severe selenium (Se) contamination and toxicity in a mob of lambs grazing the pasture. Resultant testing raised significant concerns regarding the suitability of offal for human consumption.

Introduction and case analysis

In July 2021, 250 lambs were introduced to fresh pasture before being yarded for shearing overnight. Six lambs died overnight and five died the following day. Post-mortem examinations revealed dehydration and inflamed intestines, with a presumptive diagnosis supporting clostridial deaths. Following treatment with Tetanus and Pulpy kidney toxoid, as well as a multivalent clostridial vaccine the lambs were moved to older pasture. Two additional lambs died, totaling 13 fatalities.

An unrelated investigation into selenium toxicity in horses unveiled a selenium application error. Sodium selenate was excessively-applied to 3.5 hectare (ha) at a rate of 1.6kg sodium selenate/ha or 0.66kg Se/ha - 65 times the recommended dosage of 10g/ha. Pasture selenium levels, tested eight weeks post-application, reached 13.6mg/kg dry matter (DM), far exceeding the normal range (up to 1mg/kgDM).

Blood and liver sampling

The lambs had access to the selenium-contaminated pasture intermittently for two months, starting three weeks post fertiliser application. They were then withdrawn for two weeks prior to blood testing. This testing revealed an average blood Se level of 14,000nmol/L (range 250–2000nmol/L), which prompted further testing, as this level exceeded the value of 4400nmol/L identified by Millar and Meads (1988ab) that may place the liver and kidney above the safe level for human consumption.

Liver biopsies, as well as kidney samples from one euthanised animal were taken on the 6th of September 2021 with results displayed in Table 1.

Table 1. Results of liver, blood and kidney samples taken on the 9th of September 2021.

	Liver (nmol/kg)	GPx (KU/L)	Serum (nmol/L)	Blood (nmol/L)	Cortex (nmol/kg)	Medulla (nmol/kg)
Right ear #1	136878	41	4627	18750		
Left ear #2	95393	44.6	4970	13849		
Poll #3	65692	45	4364	13281		
Nose #4	65625	42.6	3594	13111	4636	22085
Shoulder #5	49082	48.2	3567	10141		
Range	450–15000	4–100	140–3000	250–2000		
Average	82534	44.28	4224.4	13826.4		

Follow on testing and preparation for slaughter

The results from this sampling prompted further discussions around the suitability of offal for human consumption, considering the lambs were approaching slaughter weight targets. The maximum safe level of selenium in liver for human consumption is noted to be 25,000nmol/kg. The results from the lambs sampled were two to five times this amount, with lamb #1 at a level suggesting just 40 grams of liver would exceed the maximum safe daily intake of 400ug (World Health Organisation 1996).

The serum and GPx testing was repeated three weeks later with results displayed in Table 2. This did not indicate significant decreases in selenium levels, but with serum not being the storage organ for selenium, further liver sampling was undertaken to facilitate discussions for special slaughter conditions. Trends were assigned to these results to predict when offal tissues would be safe for human consumption. Calculations were made and ultimately a notice of direction was supplied that allowed for the slaughter of the affected animals provided kidneys were discarded. The lambs were slaughtered on the week of 25 October 2021.

Table 2. Full results from all testing performed on the lambs from September to October 2021.

		6 Sep 2021						23 Sep 2021		6 Oct 2021
		Liver (nmol/kg)	GPx (KU/L)	Serum (nmol/L)	Blood (nmol/L)	Cortex (nmol/kg)	Medulla (nmol/kg)	Serum (nmol/L)	GPx (KU/L)	Liver (nmol/kg)
Right ear	#1	136878	41	4627	18750			3011	38.5	30252
Left ear	#2	95393	44.6	4970	13849			3348	35.3	20044
Poll	#3	65692	45	4364	13281			3299	30.4	23111
Nose	#4	65625	42.6	3594	13111	4636	22085	2912	41.3	19785
Shoulder	#5	49082	48.2	3567	10141			2256	48	14669
Range		450–15000	4–100	140–3000	250–2000					450-15000
Average		82534	44.28	4224.4	13826.4			2956.2	38.7	21572.2

Discussion

Selenium is important in the body to help maintain cell membranes, as well as regulating antioxidant and immune functions (Grace *et al*. 2010). Excretion is mostly through faeces in ruminants (Langlands *et al.*1986), with some exhaled or excreted in urine especially in toxicity cases. Majority of the total Se in the body is associated with muscle, but when concentration in tissues is considered, the highest levels are in the liver (0.8umol/kg tissue) and kidney (7umol/kg tissue) (Grace *et al*. 2010). This, alongside the inability to easily test target organs repeatedly, and cost considerations, prompted investigations into how blood could be used as an indicator of toxicity levels in kidneys.

Considering the concentration of Se in red blood cells is reflective of the environment they were made in, and the life span of a red blood cell is 5–6 months (Wright 1965), it was going to be a considerable time until we would see depletion of GPx activity or blood levels regardless of target organ levels. Serum Se is more indicative of the current environment and declines faster than whole blood and liver levels. This made it a more practical early indicator of decreasing concentrations in tissues if repeated samples were to be taken, to prioritise taking liver biopsies once the serum levels had dropped instead of consistently repeating biopsies. Ultimately, the timeline the farmer needed to follow, led to the process being cut short and repeated serum samples not being possible before the lambs left the property.

Pasture and selenium management

On 6 June the farmer had applied 5.5kg of sodium selenate to 3.5ha. This gave a rate of 1.6kg sodium selenate per ha. Which equated to 0.66kg Se/ha (min 41% Se in Na_2SeO_4). The recommended rate of application is 0.01kg/ha (10g/ha).

Sodium selenate exhibits rapid uptake in plants, peaking at ~3–4 weeks post-application and returning to baseline in ~120 days at standard rates (10g/ha)(Grace and West 2006). Given the over-application, high selenium residues persisted longer. Serial pasture samples were taken and results displayed in Table 3.

Table 3. Pasture sampling results in fresh pasture and silage samples from August 2021 to May 2022.

Pasture samples (mg/kgDM)					Silage
17.8.2021	23.9.2021	14.10.2021	2.5.2022	Range	2.5.2022
13.66	59.5	15.97	3.35	(0.05-0.15)	.048

On 17 of August pasture samples were taken of the paddock in question, revealing Se results of 13.6mg/kgDM (normal results up to 1mg/kgDM). Considering maximum levels should be reached within 3–4 weeks of application and this was now eight weeks post, we can assume that the levels when the lambs were exposed were considerably higher, when samples were repeated, levels initially increased even further before decreasing over the following eight months as expected. The pasture was rested during this period, with (non selenised) fertiliser applied to attempt to speed up grass growth, with the intention of increasing plant utilisation of Se for growth. Eventually, silage was cut off this paddock and tested to ensure safe feeding levels, before being sold to a farmer with diagnosed selenium deficiency in cattle.

The recommended daily dietary requirement of Se for a sheep in NZ is 0.03mg/kgDM (Grant and Sheppard 1983), and when eating 3% of their body weight in DM, a 30kg lamb will require 0.27mg Se per day. In this scenario with 13.66mg/kg DM, 30kg lambs would have been taking in 13mg Se per day, if an absorption co-efficient of 0.2–0.6 is used (Harrison and Conrad 1984), around 2.6–7.8mg Se was being absorbed per day.

Where acute toxicity manifests itself similarly to other causes of acute death because of circulatory failure, chronic toxicity is associated with loss of appetite, lameness, poor growth and wool or hair production (Clark 1993). Some of the lambs on this property were losing wool, but they had no ill-thrift or decreased growth rates and none of the stock displayed lameness.

Conclusions

The case highlights the critical importance of precision in trace element management, to avoid severe consequences for livestock health and public safety. It also demonstrates how important it is to have a whole farm approach when investigating clinical issues. If it weren't for the investigation into lameness in the horses on the property highlighting the selenium excess in pasture, there could have been serious consequences resulting from the export of offal exceeding the safe level of selenium for human consumption.

The toxic selenium levels in pasture as a result of a miscalculation when applying sodium selenate endangered all of the animals that grazed intermittently on the contaminated paddocks. Pasture management strategies included resting the contaminated paddock, applying non-selenised fertiliser to enhance plant growth and selenium uptake, and monitoring forage selenium levels. Liver biopsies and serum tests were used to track selenium depletion in the lambs and guide the timeline for slaughter under controlled conditions to ensure food safety.

This case further emphasizes the value of collaborative efforts between veterinarians, farmers, and regulatory bodies to mitigate risks associated with selenium toxicity and manage the safety of our food chain. Restrictions in place due to COVID Level 4 restrictions at the time this case unfolded meant that cooperation both within the clinical team and between different industry members was important. This allowed the clinical findings in the horses on the property to ultimately save potentially devastating effects on the downstream food chain.

References

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