Sheep, Camelid and Goat Veterinarians Conference

Proceedings

Wagga RSL Club, Wagga Wagga, NSW
30 June to 2 July 2021

Debrief, Reboot and Retool

2021 Sheep, Camelid and Goat Veterinarians Conference

with a Sheep Reproduction Stream

KNOWLEDGE

100 YEARS AND BEYOND | AUSTRALIAN REPRODUCTIVE VETERINARIANS

100 YEARS AND BEYOND | SHEEP, CAMELID AND GOAT VETERINARIANS

Welcome

On behalf of the Australian Sheep, Goat and Camelid, and Reproduction SIGs executive committees I would love to welcome you all to Wagga Wagga. This is the first face to face program the AVA has put on post COVID hitting our fine Australian shores. I am personally thrilled that it is a sheep conference in a rural town that is very accessible to many of our small ruminant veterinarians in Australia. No doubt this has helped us get plenty of people in attendance.

This conference is only possible due to our sponsors, and I wish to thank each of you for continuing to support our profession. The sheep (and agricultural) industry has not looked so strong since the wool boom in the 1950's, obviously not many of us remember these times but fortunately we have some great wisdom amongst the crew in attendance that can remember. The current profitability in Australian farms provides a great opportunity for professionals to get amongst the small ruminants and their producers. We have to continue to promote the skills and support we have to offer.

I do not need to go into the conference program, as you have obviously seen enough in it to get you here. But I do want to thank the hard working volunteers Susan Swaney, Tim Gole, Dione Howard and Scott Norman. This event doesn't happen without a lot of time preparing the content and we really appreciate the program you have all worked hard to bring together.

I hope you all enjoy the conference, I would ask you to think about the three main reasons you are here. For me it is about learning something new. It is also about getting away from the everyday work that is my job, but most importantly I believe conferences are about networking with your colleagues. We need to develop friendships within our community and I would encourage all of you to make the effort to get to know people that you wouldn't normally spend time with. Let us all leave here with a few extra phone numbers of like minded people that we can call upon in times of need or be there to support. Everyone has a lot to offer at the conference, let's make these three days resourceful and entertaining.

Regards,

Andrew Whale, SCGV President

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Table of Contents

The Australian Sheep Sustainability Framework – a world first

Prof Bruce Allworth, Steering Group Chair, CSU

Introduction

The Australian Sheep Sustainability Framework (SSF) was launched by Sheep Producers Australia and Wool Producers Australia in April, 2021, after extensive consultation with key industry and customer stakeholders. It is the first sustainability framework for a sheep industry anywhere in the world.

The Framework

The Framework was developed by an industry-led Sustainability Steering Group and followed a year of close consultation with industry stakeholders and the broader community. Using an AA1000 Assurance Standard for Materiality, the Framework was developed to report data on sustainability priorities identified as being important to stakeholders.

The Framework will enable the sheep industry to:

- demonstrate sustainable practices,
- identify areas for improvement, and
- better communicate with customers and consumers.

The framework lists 21 priorities across the four themes - *Caring for our Sheep*; *Enhancing the Environment and Climate*; *Looking after our People, our Customers and the Community* and *Ensuring a Financially Resilient Industry*.

It is expected that the Framework will produce annual Reports, providing up-to-date and robust data on the 60 metrics identified to be reported. This will enable both the industry and its customers to track progress over time on the important areas agreed to during the extensive consultation period.

Both lamb and wool are premium products, and customers and consumers have increasing expectations about the practices relating to their production. The Framework, through its regular reporting, will provide an opportunity for industry to further enhance trust and transparency around its sustainable practices, and provide a mechanism to show when improvement is occurring.

Importantly, the Framework is not a policy instrument – it will report on practices, but it will be up to the industry to decide if any changes to those practices are needed.

Relevance to Veterinarians and Producers

For veterinarians, the Framework puts animal welfare and best practice sheep production, including the use of pain relief, front and centre. The theme Caring for our Sheep, there are 17 metrics, with two on pain relief (pain relief for mulesing, and pain relief for castration and tail-docking), and four metrics relating to on-farm best practice (scanning for twins, vaccination, and adoption of non-mulesing(two metrics)). The Priorities are on husbandry practices, best practice management, preventing and managing disease, and on-farm euthanasia highlight how import these areas are to all stakeholders. While the Framework aims to increase trust and transparency around sheep industry sustainable practices, and does not specifically require individual producer action, it provides veterinarians with an increased understanding of the importance of their input into the sheep industry, and is likely into to the future to be indirectly promoting more veterinary input on sheep farms. The Materiality matrix (figure 1) emphasises this.

Figure 1. Materiality Matrix from the Sheep Sustainability Framework document

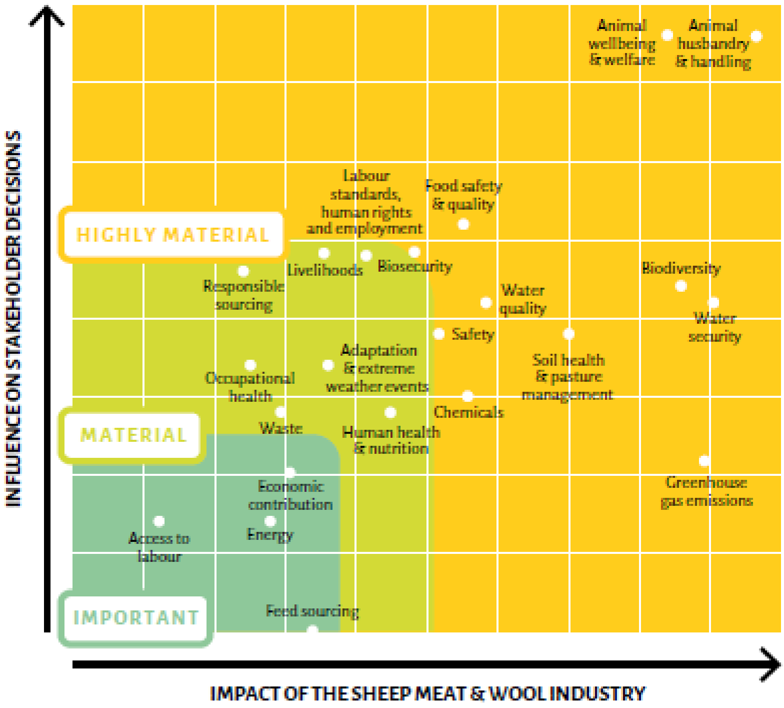

Figure 5. 2021 materiality matrix for the Australian sheep industry

For producers, there is no specific impact or action required. The reporting process will be managed at a national industry level, and while it will report on some on-farm activities, there is no additional reporting burden on producers. Producers are, however, encouraged to become familiar with the Framework, to enable them to be aware of the performance of the industry on key sustainability practices. This will better position producers to identify and respond to important issues which relate to their business, and more easily promote their on-farm practices. The Framework will not influence or impact on individual arrangements farming business have to promote their sustainability practices with specific brands.

Final comments

The Sheep Sustainability Framework will be a living document, subject to review and refinement so that it remains relevant and meets the expectations of all stakeholders. This ongoing commitment to transparency, continual improvement, and engagement will ensure the Australian sheep industry remains a strong and important industry for its participants and its customers.

The Framework can be found at www.sheepsustainabilityframework.com.au

Pain Mitigation resources for sheep

https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/animal-health-welfare-and-biosecurity/20mla-pain-mitigation-factsheet_general_v5.pdf https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/animal-health-welfare-and-biosecurity/20mla-pain-mitigation-factsheet_sheep_v4.pdf

Sheep abattoir surveillance in South Australian – past, present, future

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Introduction

The South Australian Enhanced Abattoir Surveillance program (EAS) has been at the forefront of disease and condition surveillance in sheep in Australia since 2007. It has been operational in Thomas Foods International (TFI) South Australian (SA) export abattoirs at Lobethal and until 2018 at the Murray Bridge plant (which was impacted by fire in 2018). The program has been funded by both the SA and National Sheep Industry Fund, and currently by the SA Sheep Industry Fund, Animal Health Australia and the MLA Donor Company (MDC) a fully-owned subsidiary of Meat & Livestock Australia (MLA). It is managed and administered by Biosecurity SA, a division of Primary Industries and Regions, South Australia (PIRSA).

Project objectives

1. To give real time feedback to registered South Australian sheep producers who directly supply TFI South Australia, about specified diseases and conditions in their sheep, detected at the abattoir, and to provide management information on these diseases and conditions.
2. Inform the SA sheep industry annually about region specific sheep health trends observed in sheep in SA during abattoir surveillance.
3. Provide national reports to Animal Health Australia (AHA) / National Sheep Health Monitoring Program (NSHMP), and Livestock Data Link (LDL).
4. Assist in maintaining SA's overall livestock biosecurity capacity and capability by using a passive (general) surveillance system, thereby increasing market confidence and market access.

Abattoir surveillance background

Abattoir surveillance provides information to producers about diseases and conditions in their stock which are very often hidden or "silent" on farm. South Australian producers consigning to TFI are the only producers in the country to receive twice weekly "real-time" feedback reports on diseases and conditions detected in their sheep on abattoir inspection. Feedback provided is in addition to routine processor condemnation information and includes information on over 20 conditions. This timely and comprehensive feedback enables producers to make management changes to improve biosecurity, maximise production efficiency on farm, and to minimize trimming and carcase condemnations at the abattoir and hence increase profitability. In turn, animal welfare and the health of the flock is improved, both of paramount importance to secure trade access in current and future market opportunities.

Current program

Around 9000 feedback letters or emails are sent to registered South Australian producers each year, as well as relevant associated fact sheet/s being sent with letters. More broadly, the program also aims to inform the sheep industry of relevant sheep health trends occurring in SA through an annual report and region-specific annual benchmarking reports.

Since November 2019, South Australian data is visible to producers registered on One Biosecurity, with all future results (from the date they register and set up an account with One Biosecurity) being visible online (https://www.onebiosecurity.pir.sa.gov.au/Home). Since late 2018, results are also available on Livestock Data Link, which is updated monthly with new South Australian data (https://www.mla.com.au/research-and-development/livestock-data-link/).

Annually, surveillance is performed in around 1.5 million sheep, from over 2000 South Australian properties from all regions of SA. For all consignments (lines) of 50 or more sheep processed, third party independent meat inspectors are required to record the estimated percentage of the line affected in 5 percent increments (prevalence) with any of the 21 specified diseases and conditions. As part of a separate program, Ovine Johnes Disease is inspected on producer request in mutton lines of any number of animals by the same meat inspectors.

Meat inspection involves inspecting the carcase and its red and green offal, assessing it for any health conditions, communicating this information with other meat inspectors at the end of a line and accurately recording the percentage of the line affected on a computer database positioned on the kill floor. This reflects conditions and diseases occurring at a level that could be considered a 'flock' problem and worthy of reporting to producers. Consignments with less than 5% of conditions detected are recorded as clean lines (0%), and emails are sent to these producers with this information if they have an email address recorded with their property registration.

To provide confidence to producers and industry about the data generated by the EAS program, annual training of meat inspectors regarding the abattoir surveillance program takes place. In addition, inspection verification regarding ability to correctly identify the conditions and diseases specified as part of the EAS program was assessed by MINTRAC (the National Meat Industry Training Advisory Council Limited) in 2020, with the inspectors having a higher inspection accuracy than the accepted training thresholds. In 2015, meat inspectors were assessed for accuracy of estimates of disease and condition prevalence, with their estimated prevalences being found to be within 10% of the true prevalence, which was considered very acceptable[1].

Research using historical de-identified data is ongoing to drive improvement both on-farm and supply chain performance, to benefit the livestock industry. A large project funded by MLA with University of Adelaide will end in 2022, and it is hoped that a cost-benefit for each condition and a business case regarding a national surveillance program will be proposed.

The most significant conditions affecting producer and processor productivity and profitability are grass seed infestation, pleurisy and pneumonia, and arthritis. Specific projects have investigated the impacts of these conditions [2-7].

Future

There is a push from the sheep industry to seek individual carcase, disease and condition data using technologies such as Electronic ID. There are different technologies being trialled to obtain individual sheep data, such as headset/voice recognition and touchscreens. The goal is to efficiently gather, analyse and synthesise data to inform producers regarding on-farm management and production decisions.

Conclusions

Abattoir disease and condition feedback is a valuable source of information for both sheep veterinarians and livestock advisors as well as producers. Feedback can alert producers about hidden diseases and conditions on farm, which can then be used to make management changes to improve biosecurity, maximise production efficiency and profitability, and to improve animal welfare and flock health. Associated annual regional benchmarking reports also enable producers to compare diseases and conditions in their enterprises against others in their region.

Online resources – see pir.sa.gov.au/eas

The **annual report** is available at: https://pir.sa.gov.au/biosecurity/animal_health/sheep/health/enhanced_abattoir_surveillance_program#toc6

The **regional benchmarking reports** are available at: https://pir.sa.gov.au/biosecurity/animal_health/sheep/health/enhanced_abattoir_surveillance_program#toc7

A suite of **factsheets** about the diseases and conditions assessed are available at: https://pir.sa.gov.au/biosecurity/animal_health/sheep/health/enhanced_abattoir_surveillance_program/diseases_and_conditions

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Climate impacts versus adaptation and mitigation strategies for agriculture

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Introduction

This paper examines the likely broad scale impacts of anthropogenic climate change on Australian agriculture and broad scale adaptation and mitigation opportunities for Australian livestock systems.

Climate Change Impacts

Climate change has already affected Australian agriculture due to warming, changing precipitation patterns (particularly strong declines across much if the southern half of Australia), and greater frequency of some extreme events[1]. Climate change has resulted in lower animal growth rates and productivity in many pastoral systems[1] and there is robust evidence that agricultural pests and diseases have already responded to climate change resulting in both increases and decreases of infestations[1].

The risks of climate-related impacts are highly context-specific but expected to be higher in environments that are already hot and have limited socio-economic and institutional resources for adaptation[2]. Large uncertainties remain as to climate futures and the exposure and responses of the interlinked human and natural systems to climatic changes over time[2]. Consequently, adaptation choices will need to account for a wide range of possible futures, including those with low probability but large consequences.

The possible impacts of climate change on forage availability, will differ considerably by location and species. For global rangelands mean herbaceous biomass could decrease by 4.7% by 2050, with 74% of global rangeland area projected to experience some decline in mean biomass[3]. The largest regional decrease is projected for Oceania while the highest increase was found for Europe. Woody encroachment is also projected to occur on over 51% of the global rangeland area by 2050[3].

Climate Change Adaptation and mitigation options

Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and co-operation at all scales and can be enhanced through integrated responses that link mitigation and adaptation with other societal objectives[1].

Adaptation can take a variety of approaches depending on its context in vulnerability reduction, disaster risk management or proactive adaptation planning.

At the broad scale these include:

- Social, ecological asset and infrastructure re/development;
- Technological process optimization;
- Integrated natural resources management;

- Institutional, educational and behavioural change or reinforcement;
- Financial services, including risk transfer; and
- Information systems to support early warning and proactive planning.

The livestock sector is vulnerable to climate change and related policy in two ways. First, livestock production and performance are directly impacted by climate with many projected effects being negative.

Second, the sector may need to alter operations to limit the effects of climate change through adaptation and mitigation.

Potential adaptation strategies involve land use decisions, animal feeding changes, genetic manipulation and alterations in species and/or breeds. In terms of mitigation, livestock is a substantial contributor to global non-CO2 greenhouse gas emissions.

Mitigation opportunities involve altered land use for grazing and feed production, improved pastures and/or feeding practices, manure treatment and herd size reduction. In addition, strengthening institutions that promote markets and trade, as well as local support programs can help.

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Drought versus production feeding of sheep

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The sheep grazing areas of Australia have encountered a significant drought approximately every decade since Federation[1]. Considering the consistency of these events over the last 120 years of records, it is unlikely that this pattern will change over coming decades. Risk identification and management is a fundamental requirement of the directors of publicly listed companies and it is clearly in the interests of private farming enterprises to identify and address such a significant risk to the business as interruption to the supply of the basic input of feed (and in some cases water) to the animals responsible for the primary business output. The most recent drought, accompanied by strong markets driven by the global demand for protein, has seen a large proportion of sheep enterprises respond to the lack of pasture by building containment feeding facilities and the infrastructure necessary to mechanically provide feed. Many of these are no longer seen as a single use survival opportunity, but as a resource to strategically manage feed gaps on an ongoing basis.

The move to containment feeding of various classes of stock has highlighted the need to meet the specific requirements of the stock class for a target production outcome. For breeding stock, there are many tools available to estimate their metabolisable energy (ME) requirements[2]. It is prudent to calculate ME requirements using the upper limits of the ranges provided from these tables and note that the mean body weight of many modern meat sheep exceeds the weight ranges quoted and requirements must therefore be scaled accordingly. As energy is the first limiting nutrient, we calculate ME requirements first, then correct to meet the minimum protein requirement. Note that the factorial calculation of protein requirements described by CSIRO[3] estimates the minimum protein necessary to provide sufficient nitrogen to the rumen microbes to adequately utilise the available carbohydrate. These figures are minima, not targets. The minimum dietary crude protein (CP) concentration necessary to ensure that nitrogen supply will not limit microbial crude protein production regardless of the rate of carbohydrate substrate supply is 13%[4,5]. Protein does not only provide protein, but amino acids also provide a substrate for gluconeogenesis after deamination. In practice, the inclusion of a pulse as a high ME ingredient will also result in protein requirements being met and exceeded.

Where roughage is available, we have the option of estimating the ME requirements for the given mature stock class, and to use neutral detergent fibre (NDF) as the primary limit to voluntary intake, rather than programme feeding. This is based on the NDF based intake estimation equation[6].

120/NDF = % of body weight (BW) as dry matter intake

The scaling factor is derived from feed intake in dairy cows[7]. Sheep have a potential dry matter intake similar to dairy cows, so the application of the equation is appropriate (not for intensively fed beef cattle which eat considerably less on a BW basis). We can therefore modify the intake estimation equation to nominate a target intake as a proportion of BW, thus:

NDF = 120/target % BW intake as dry matter.

Therefore, if we want to provide an intake of 2.5% of BW, the dietary NDF concentration required to limit intake is 48%. We then specify this NDF figure, the ME concentration to meet[4,5] requirements at the nominated intake, and the minimum dietary CP requirement, in a least cost ration formulation programme to calculate the ingredient composition of the mixed ration. Limiting intake with NDF concentration has benefits in the uniformity of the condition of the mob and in animal welfare.

Successful containment feeding requires monthly recalculation of requirements as demands due to pregnancy increase, and should always be monitored by regular (at least monthly) condition scoring. If ewes are to be held in a confinement facility until late pregnancy their macromineral requirements must be met[8] for the duration to ensure they have adequate minerals for foetal skeleton mineralisation.

No growing sheep should ever be fed for "maintenance" or a target growth rate below their potential. Feeding for low production dramatically increases feed conversion ratio (which asymptotes at infinity for zero BW gain) and this logically results in illogically high cost of gain. With growing sheep, we target the highest possible energy density that is compatible with rumen health (ionophores play a valuable role here), feed them for a target market, and turn them off as soon as possible.

With the feeding of wool or dual-purpose sheep, depending on relative feed pricing, we aim to provide approximately 20% of the CP as undegradable dietary protein (UDP) with a focus on a UDP amino acid mix rich in sulphur containing amino acids to maintain wool growth and tensile strength.

Before any stock are fed, business logic demands that a feed budget must be run, and this provides the inputs into a financial budget. This will allow consideration over time of reducing the numbers of stock fed, as sale sheep are marketed, and should include a trigger where the flock will be sold down to a minimum number of breeders that can be fed for a prolonged period in terms of labour, infrastructure, and cash flow. If the market is strong this number could be zero. To serve our clients well, the tools to manage the next drought should be in place before the next drought. An impediment to effective drought risk management by efficient producers is provided in the form of drought subsidies and relief, every decade when a major drought occurs. It is in the interests of efficient and financially aware producers that such government largesse is abolished, as such producers are currently placed at a competitive disadvantage by these handouts.

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The ethics of sheep production: emerging issues

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The views in this paper represent the thoughts and opinions of the author.

Introduction

The rise in interest in animal welfare and the sustainability and ethics of food and fibre production in developed societies is influenced by increased urban living and greater wealth over time. With food security and immediate personal needs no longer a daily challenge for many people, society's 'circle of moral concern' has been expanding. As would be evident from any perusal of the media and electronic discourse, the ethics of agricultural land use and of animal-based food and fibre production are very much within this orbit of concern and scrutiny. Although it is not possible to predict the future, an examination of emerging trends may help to identify some challenges and opportunities for sheep production.

Emerging trends

Once upon a time, within the working lives of some of our delegates, and within the memories of most, Australian governments, typically at both the state and federal level, saw it as one of their roles to assist primary producers in producing more, producing more efficiently, and with healthier animals in relation to endemic diseases. This was enacted through government-funded research on animal productivity and health, and communicated through government-funded extension programs to farmers. Today, apart from areas such as exotic disease incursion, government programs are not so much about assisting farmers in their animal production, but rather in ensuring the Australian community's expectations are met in terms of *how* such production is undertaken – in relation to environmental stewardship, animal welfare and food safety.

Another obvious trend is one that the wool producers have had to face for many years, and is now starting to become a reality for meat and milk producers – the development of artificial or plant-based analogues or replacements for animal products. Plant-based meat substitutes are currently capturing a lot of attention, but future developments in biotechnology are likely to reduce the cost of 'bioreactor milk' and 'meat' that are biochemically and organoleptically indistinguishable from that derived directly from animals.[1]

Animal welfare

During the past century, community views on animal welfare have moved from being concerned only with acts of wanton cruelty toward animals, to concerns about standards of animal care. An area of focus of this public concern has been systems where animals are kept for profit, such as agriculture. Intensive farming systems, where animals are managed in man-made environments, have received particular attention from animal welfare interest groups, and were the subject of the first farm animal welfare campaigns and regulatory scrutiny during the 1960s and 1970s. More recently, extensive animal production systems have also faced questions about the standards of animal welfare involved in food and fibre production.

Many people prefer to differentiate between defining *animal welfare* as a concern for the highest standards of care for animals, and *animal rights* as a philosophical concept that translates into an avoidance of the utilisation or exploitation of animals. In practical terms, the lines are often blurred, and as my colleague A/Prof David Beggs has eloquently argued, people tend to conflate animal welfare and ethics, whereas animal welfare refers to the state of the animal, and ethics refers to the human concepts of what is right or wrong in a situation.[2] As veterinarians, we work to ensure that the health and welfare of sheep are optimal, and yet we need to be prepared that people with differing ethical frameworks to our own may believe that this is not highly relevant because we should not be farming these animals anyway.

Surveys in western countries such as Australia show animal welfare ranks low compared with health, education, the economy, and law and order.[3] However, animal welfare is still sufficiently 'on the radar' of many people to enable a particular issue or controversy to gain strong traction. Because the business of farming utilises animals for profit, it is not surprising that many animal welfare queries are related to animal production systems, along with animals in scientific research and display, entertainment and sport, as well as the breeding and management of companion animals, particularly dogs.

One really interesting piece of data has been collected by Coleman and colleagues in relation to not just societal attitudes to farm animal use and welfare, but the background factual knowledge of people in relation to their attitudes.[4] In this research, Australian public attitudes toward animal welfare showed that laying hens were perceived to have the lowest welfare of the farmed species, and that wool sheep were perceived to have the highest welfare (with meat sheep also being in the positive part of the graph). Interestingly, the correlation between self-perceived knowledge and actual knowledge of farming practices was statistically significant, but very low. More worryingly were the results relating to the subset of individuals that Coleman and colleagues termed 'opinion leaders' within their social network, based on their activities. These people expressed more concern about animal welfare in farming, reported greater *self-perceived* knowledge about practices than the wider public, but in reality had no greater *actual* knowledge.[4]

Future ethical constraints

Much of the focus of the preceding section has been on how animal welfare may intersect with ethical concerns and viewpoints. It is important to recognise that this serves as an example of what may also happen in relation to issues such as environmental stewardship, mitigation of climate change, indigenous rights and social justice. Although there is a portion of our society (and of veterinarians) who have an ethical viewpoint that the farming of animals is inherently wrong, it is my opinion that the more influential discussion (and hence risk/challenge for the livestock industries) will be with people who come to believe that certain animal farming is *inappropriate* in the manner/context/location in which it may be occurring.

As an example, let us consider mulesing of sheep. At the height of the initial controversy in the early 2000s, the debate understandably focused on welfare impacts on sheep of mulesing compared with flystrike, the likelihood and pace of potential genetic approaches, and then the quantitative benefits of analgesia and alternative procedures. However, an underlying discussion was not so easily dealt with at the time – that being '*if you have to perform such a traumatic and painful procedure to livestock in order to prevent an even more painful and debilitating condition from occurring, should you really be farming these animals in this environment in the first place?*'

Conclusions

Unless there is a severe economic downturn, social upheaval or environmental challenge that threatens the security and production capacity of animal-derived foodstuffs, it is almost certain that the need to address ethical questions within animal production systems will remain and grow. Yet feeding the world while addressing climate change is one of the biggest challenges of the 21st century. The world's population is expected to exceed 9 billion by 2050. Agricultural production will need to increase by an estimated 70%, according to the UN Food and Agriculture Organization, with strong demand projected for commodities such as milk and meat.[5] Thus, Australian farmers have a wider opportunity to help feed and clothe the world, so long as the ethical expectations of voters and consumers closer to home can be met.

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Confinement feeding sheep - Veterinary learnings from the 2018-2020 drought

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Introduction

Good winter rainfall in winter 2016 saw the Coonamble district through most of 2017, with some supplementary feeding in the paddock towards the end of the year. By early 2018 producers were finding that ground cover was severely depleted and were making the decision to confine animals and fully hand feed. The district managed to maintain around 60-70% of pre-drought sheep numbers, in comparison to 20-30% of pre-drought cattle numbers[1]. Most of these sheep were fed in confinement pens until March 2020 when drought-breaking rain was received across the district. The effects of feeding sheep on a cereal grain-based diet, with little or no pasture, for at least two years was challenging and brought with it a gamut of veterinary and nutritional issues which will be discussed in this paper.

Basic Sheep Nutrition

Drought feeding nutrition, regardless of the class of stock, must centre around the provision of adequate metabolisable energy (ME), which is expressed as Megajoules or MJ ME/kg dry matter (DM).

Energy requirements of adult sheep are outlined in Table 1:

Class of sheep	Requirements MJ ME per day
50kg ewe dry sheep	8
50kg last month pregnancy (single)	13
50kg last month pregnancy (twin)	18
Lactation (single)	16-26
Lactation (twin)	21-34

Table 1: Energy Requirements of Adult Sheep[2]

When energy substrates (such as starches, simple sugars, fibre and the carbon skeleton from protein molecules) enter the rumen, they undergo fermentation by the rumen microflora producing volatile fatty acids (VFAs). There are three types of VFAs – acetate, propionate and butyrate. Propionate is the most efficient VFA to channel into producing blood glucose. In a drought feeding situation, blood glucose is essential for survival, but also for weight gain, growth of foetuses, maintenance of the dam, and milk lactose production. Starch is good at producing propionate, hence many of our drought feed rations for sheep are based around starch, provided in the form of cereal grain.

The downside of feeding a starch-based diet is the risk of acidosis which is a major challenge in drought feeding. To manage acidosis, and to promote comfort, relief of boredom, cud chewing and salivation, it is recommended that hay be provided in confinement pens and that the animals be eating at least 10-15% hay in their diet. Other than in an early weaning situation (where better hay quality is advantageous) the quality of the hay does not matter, and often straw or poorly palatable very fibrous hay is used to help restrict intake. Because the hay is available ad libitum and intake will vary, it is recommended that the daily energy requirement of the sheep be provided via the cereal grain portion of the diet and the hay/straw be an added extra.

While many farmers will assume that an animal will eat 3% of body weight, there is a more accurate way to calculate this, based on how fibrous the diet is. The more fibrous, the higher the Neutral Detergent Fibre (NDF), which is easily measured on a feedtest. The higher the NDF, the more time the rumen will take to digest the feed and the less the animal can physically eat each day. With poor-quality hay and some silages, this will be performance limiting (ie. they won't be able to physically eat enough each day to satisfy their requirements and will lose weight). A very useful equation that is used to determine the likely intake of a ration is[3]:

$$\frac{\text{Bodyweight of the Animal x 1.2}}{\text{NDF}}$$

Protein requirements for maintenance of adult animals are also worth considering, and are outlined in the following table:

	Minimum crude protein %
Dry Sheep	6
Ewe – last month pregnancy	8
Ewe – lactation	12

Table 2: Adult animal minimum protein requirements[4]

Extra protein provided above maintenance is not clinically detrimental unless provided in very high amounts (above around 23%). Surplus protein will be cleaved, and the carbon skeleton used as an energy source, while the ammonia compound is detoxified in the liver for excretion by the kidney. This can be an energy taxing process though, and in a drought when every MJ of energy counts, it is not ideal. Many producers, at least at the start of the drought, were very protein focused and it must be stated that more is not better!

As commodity prices fluctuated through the drought, producers bought by-products, novelty feeds and things that they were not familiar with. The oil content of some of these products, for example cotton seed and grapemarc, will exceed the 6% tolerable threshold of a rumen and must be considered if included in the diet in large quantities.

The following table outlines not only the energy and protein content of the most commonly used grains, but also oil and starch contents, which are very useful when considering what a ration might be doing to a rumen:

Average Values (Grains)

Grain	ME	CP	Starch	Oil	Fibre	% RDP CP
Wheat	13.5	13%	76%	2-3%	1- 2%	80%
Triticale	13.0	13%	76%	2-3%	2- 3%	
Maize	13.0	8%	76%	2-3%	2- 3%	50%
Sorghum	13.0	12%	70%	3-5%	2- 3%	
Barley	13.0	12%	61%	5-7%	3- 5%	80%
Oats	12.0	10%	42%	12-25%	7-10%	80%
Cotton Seed	13.0	21%	38%	12-21%	24%	60%
Lupins	13.0	35%	<10%	10-15%	5- 9%	80%
Peas	12.5	25%	48%	9%	0.5%	
Beans	12.5	25%	37%	11%	1.5%	

Table 3: Nutritional value of common grains[5]

The ruminal cardia (or outflow tract) in a sheep is 2mm wide, meaning that most cereal grains cannot escape without being broken down structurally (and likely fermented). The grain will stay in the rumen and be digested or be eructated and chewed in the cud repeatedly until the digesta is less than 2mm. This is the reason why processing of grains is not essential in sheep rations. However, in a mixed ration, for example barley and lupins, it can be useful to process the larger grains to match the particle size and avoid sorting. In the Coonamble district this usually involves cracking the lupins into 2-3 particles.

The NSW DPI Drought Feeding Calculator[6] is available as an App for download onto any smartphone and is a really good tool to help formulate rations, calculate the tonnage of feed required and the costs involved.

Most drought feeding rations are low in calcium, and sodium. Lime and salt must always be provided in the ration. If added to the grain, 1% lime and 0.5% salt is required; alternatively, it can be provided as a 50:50 mix in drums in the pens, just ensure there are multiple access points. This also helps relieve boredom!

Many producers will include a "buffer pellet" in the ration. These are a commercial pellet that contain a variety of ionophores or buffers along with vitamins and minerals. These are typically added in at 4-5% of the ration. While pellets can be really useful to help with acidosis prevention and are also marketed to improve weight gains, palatability and sorting can be an issue (they sometimes taste bitter and the pellet size can differ from the grain size) and they can't replace attention to detail and careful feedlot management.

Diets that do not contain green feed for 6 months or more will be deficient in Vitamins A and E, so these must be supplied in the diet or via injection every 3 months after this point in the drought.

Feeding Systems

Most producers built simple, low cost confinement feeding set ups during the drought. Often, they extended their sheep yards and made do with existing water access points and facilities. Good results were achieved with basic facilities if the livestock management and care was good.

The most common feeding system consisted of self-feeders filled with grain; and hay in racks separately. Providing hay in racks, so that the animals are not eating from the ground can help prevent faeco-oral transmission of diseases like coccidia and salmonella. Most producers do not have feed mixers and instead weigh and mix rations using augers and flow rates or cattle scales.

Induction into this sort of a feeding system involves running a trail of grain out to the sheep daily, or twice daily, in the pens for the first 10-14 days, with hay provided ad lib and the grain allocation increasing every few days. After this, the self-feeders will be slowly opened to the required slot. Good guidelines on induction amounts and timelines can be found in the Managing Drought Handbook[4].

The self-feeder and hay separate system is relatively cheap and easy to set up, and the high cost items (the self-feeders) can be moved and reallocated around the farm as needed post-drought. However, allocation of the desired amount of grain, and restriction of overeating is a challenge. For this reason, this feeding system works best for weaning, or for fattening saleable animals when ad lib access to grain and hay is desirable for good weight gains. Even with self-feeders closed right down for maintenance of adult ewes, bored ewes in a confinement situation can still eat much more than their daily allocation allowing them to gain condition and risk acidosis. Changes in the weather, even just slight changes in barometric pressure, affects the appetite of animals causing them to temporarily go off and then rebound onto feed, which is high risk for acidosis when self-feeders are the grain delivery method. Producers are advised to monitor the weather and put out extra palatable hay and close self-feeders during these periods.

Some producers did build bunks or feed troughing along pen laneways to easily deliver feed from a side delivery cart. This meant that daily allocations could be more accurately delivered, enabling more stable rumen fermentation and less acidosis risk. Shy feeders could also be easily identified. The bunks or troughing did cost more to build, and were prone to contamination with faecal material, requiring sweeping or blowing before each feed.

Several fully automated feeding systems were also established in the district. These cost hundreds of thousands of dollars to build but save a lot of labour. However, the best feeding outcomes came from the producers who still spent plenty of time in the pens checking appetite, sheep behaviour, faecal consistency, grain sorting and signs of illness.

Investigating a Confinement Feeding Disease Outbreak

1. Ask

Take a good history

- age (or weight?) of animal
- origin of the stock
- how long have they been on feed
- what's in the ration, delivery method, grain processing method
- vaccination/drenching/management history
- recent weather events
- when did they first notice the clinical signs/deaths
- how many in the pens
- how many sick/dead
- farmers description of clinical signs

2. Look

It is always advisable to visit the farm, rather than have the producer bring the animals to you as it gives a lot of perspective and ground truthing of the history.

- Faecal consistency (acidotic faeces will look like pancake batter).
- What's in the feeder/mixer/silo vs what's left in the tray/bunk/trail (ie are they sorting it)
- Ration processing and particle size (too fine is an acidosis risk)
- Taste it (if it tastes bad to you, it tastes bad to them)
- Feed Access (enough trough space, heights suitable for stock, spread out enough)
- Water access, height, quality and temperature
- Sheep mob size and body weight spread (consistent body weight in the mob is probably more important than mob size, but as a guide 400 or less is a good mob size for performance and health)
- Sheep Distribution (some at feeders, some camped up chewing cud, some wandering around. If they are all in one spot there is something wrong)
- Cud Chewing is a good sign of a happy rumen
- Weather (has the barometric pressure changed, is there a heat wave or rain event?)
- Feed on the ground (hay and grain on the ground is a risk for enteric disease).
- Shade (while shade is good, congregation in small patches of shade can predispose to respiratory disease)

3. Take

Do a good thorough examination of the animals, and post mortem any clinically affected or dead stock, collecting the following samples:

- Blood (from live animals)
- Aqueous Humour (from dead animals)
- Fixed tissues of all organs
- Fresh tissues of liver, kidney, rumen contents and anything else that looks abnormal
- Faeces

And don't forget samples of feed and water.

4. Measure

Some useful diagnostic tests to do, or to ask the lab to do in most confinement feeding situations are:

- Rumen colour, consistency and odour examination
- rumen pH (performed in the field with Fisherbrand® pH indicator strips);
- rumen microscopic examination for motility (performed in the field or back in the office)
- D-lactate
- Ration analysis (full feedtest, including minerals)
- Watertest

Common Diseases in Confinement Feeding Situations

Acidosis is by far the most commonly diagnosed disease in confinement feeding situations, even when the sheep have been on a grain diet for a long period of time. Subtle changes in weather, management, feed batches and the environment can precipitate an event. This author believes that sub-clinical acidosis underpins many of the other diseases seen clinically in sheep feedlotting situations, and that a more stable rumen would lead to a lower incidence of many different diseases.

Acidosis can be tricky to diagnose in some situations. Occasionally it will present as random and sporadic sudden deaths in the biggest sheep in the mobs. In these cases, the underlying cause seems to be insufficient feed trough space, which causes some dominant sheep to overeat. In this scenario, the solution is to provide more trough space, which may feel very contraindicated! In a mob where there is a large spread of body weights, acidosis in some animals can present concurrently with malnutrition and starvation in others. This is because the bigger, bully sheep overeat, and the small, runty "shy feeders" can't or won't compete. This can be confusing unless the two conditions are considered.

Approximately 5% of sheep are shy feeders and won't eat from a self-feeder. This rate will be higher in an early weaning situation, or if the sheep aren't imprinted onto grain whist on their mothers. Sheep that are shy feeders will look underweight, hollow in the belly and are often standing in the corner on their own. They need to be drafted off and put in their own pen with plenty of good quality hay or, if there is pasture available, put out into a paddock to graze. On post mortem they will have rumens that are largely empty or contain small amounts of hay and/or dirt, have poorly developed ruminal papillae, low body fat stores, and can have concurrent disease such as coccidia or pneumonia.

Hypocalcaemia is a very common problem in the Coonamble district. It affects all classes of stock in all situations including grazing pasture, supplementation or complementary feeding in the paddock, newly arrived stock on trucks, freshly yarded sheep as well as full confinement feeding. After many years of trying various supplementation regimes, the best solution found for stock in this district is to supplement with a source of sodium and calcium for all stock, all year round. A good mix is lime/salt in a 50:50 ratio, ensuring there are plenty of points for the sheep to access the lick.

Urolithiasis (water belly) was a really common problem later in the drought when producers had shifted to feeding commercially made pelleted rations due to price and availability of whole grains. The most common types seen were struvite (MgNH4PO4), followed by calcium oxalate and calcium carbonate. It is easily diagnosed in the mob – affected animals are tucked up with ventral oedema and may be dribbling urine. On post-mortem they typically have an enlarged, inflamed bladder, with urine in the abdominal cavity and subcutaneous tissues and stones in the bladder and urethra. Low water intake can be a contributing factor, precipitated by accessibility or palatability issues. The temperature and quality of the water, especially the pH (which is typically very alkaline in the Coonamble district) affects palatability and therefore intake and should be assessed.

The mineral composition of the diet can also promote urolithiasis, so a feedtest is essential. The Ca:P ratio must be 2:1, however if the phosphorus content of the diet is >0.43%, water belly is likely no matter what the Ca:P ratio is[7]. Water belly is not commonly seen on a barley/lupin whole grain diet (if the Ca:P ratio is correctly balanced with the addition of lime) as the P content of barley is 0.4% and lupins is 0.3% (ie they are both below 0.43%). However, during the drought some of the commercial pellets contained 0.85% P despite having a Ca:P of 5:1! The solution in these cases is to add 1% ammonium chloride to the diet and to improve intake of fresh, clean, cool water.

Vitamin A deficiency started to occur commonly on farms around one year into full hand feeding with no pasture, which presented as excessive lacrimation, night blindness, ill thrift and neurological signs. It probably also contributed to many other conditions such as the development of water belly. Provision of Vitamin A (and E) in the diet using a feedlot premix, or Vitamin ADE injections every 3 months is therefore recommended if full hand feeding is going to continue beyond 6 months. The injections can cause severe pain so placement and technique are important. There were cases seen where the animals were too sore to put their heads in the trough to eat following injection into the neck, which then caused acidosis events when they recovered.

Conclusion

Drought feeding for a prolonged period is taxing not only on the animals and their health, but also on relationships, finances and mental health (of the producer and their vet)! While confinement feeding is a great strategy to carry stock through a tough time and maintain ground cover and soil structure, serious thought must be given to how long it can go on for, and whether to continue to feed, or to sell. This feeds into a much bigger whole-farm picture of cost of production and maintaining data on sheep that under-produce and are therefore the first to go when the feed cart comes out. These are all conversations that the sheep vet has a place in – we are not just there to post-mortem the dead stock when things go bad. It's important that the preparation for the next drought starts the minute the last one ends.

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What makes good extension and what opportunities does AWI have on offer?

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Introduction

A long-held frustration amongst the scientific community is gaining adoption of best practice research and development (R&D) outcomes on-farm. As with any decision, farmers have varying experiences, trusted sources of information, motivating factors, priorities and risk preferences they draw on when assessing information, and ultimately deciding whether they should implement a change or not.

Bridging the gap between R&D and adoption is a complex topic, and one that will take a unified industry approach, but that can provide innumerable benefits across-industry if we can work cohesively towards the same outcome.

Why won't farmers just do what the science proves is best?

If one is looking only from an external viewpoint at the decisions made by farmers, it could appear as though there is a lack of rational economic and scientific decision-making processes employed in their business, and that many things could be improved if they were to adopt a certain technique or improve a practice.

However, it's important to realise that simply because someone does not conform to a particular process it does not mean their methods are less valuable, only that they prefer to take in information and act on it differently, and that they have a different set of priorities and experiences that shape their decision-making processes. Decisions may seem illogical or irrational and the reasons behind them unclear, though they make a great deal of sense to those making the decision.

Rarely are farmers – or any people, for that matter – motivated solely by financial reward or facts and figures when making decisions. It is common for people to draw on a complex web of prior experiences, their values and beliefs, personal goals and ambitions and priorities, peer recommendation and review, (trusted) expert advice, their own research, their confidence to implement the decision and a myriad of other factors to make decisions – often without consciously realising they are doing so.

Traditionally, we have leaned towards a linear flow of information in agricultural extension:

1. Research
2. Trial (usually in a controlled setting, but maybe on-farm, with a few replicates)
3. Prepare workshop/flyer/brochure/research paper
4. Hold workshop/distribute flyer
5. Hope for adoption.

This has worked to some extent, probably due in the main to the sheer numbers of government extension officers of yesteryear with direct access to Department veterinarians, researchers and technical officers, but the delivery model has changed significantly in recent years and is continuing to evolve.

With this evolution we have seen a shift to the bulk of extension services being delivered by private operators, most of whom are running small businesses of 1 – 2 employees and do not always have the time to step out of their business to access up-to-date research and development.

One size does not fit all

A compounding factor to the wide-spread adoption of R&D on-farm is the sheer variety of enterprises, climates and production zones across Australian agriculture. As the saying goes, 'there are many ways to skin a cat', and this is certainly evident in the industry, with no two farms, or farmers, operating in the same way.

Adding further complication to the production variances are the differences in people's learning, behavioural and personality styles – all of which have a bearing on the way they prefer to receive information, how they best absorb it and how they interact with others. This is the main reason for using multiple mediums to support one key message, for example, face-to-face workshops which use a mixture of direct delivery, videos, audience participation using real-life examples, question time, hands-on demonstrations and take-home tools and information, short videos (e.g., YouTube-style tutorials), social media posts and traditional media to raise awareness.

The technical expert may not be the best person to deliver the message…

There is a quote which illustrates the importance of all sectors of the industry working together for a better outcome: 'Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid.'

This is not to say scientists and researchers are not effective extension deliverers, and there is certainly merit in the person who has an intimate knowledge of the subject matter sharing it, but knowledge rarely equals respect and trust. If a researcher has not had experience in delivering their findings to a non-scientific audience and does not have an appreciation for the production zone they are presenting in, or is not known to the audience, it can quickly lead to distrust and people discrediting the information as they think the presenter doesn't understand the factors affecting their production. Whether this is justified or not, perception ends up being reality and you have unwittingly created a barrier to adoption.

Extension is basically 'agricultural information marketing'

Fundamentally, effective extension and adoption relies on good marketing and communication – you're trying to sell an idea and why someone needs it or should 'buy' it. An effective marketing strategy[1] includes the following:

1. **A defined product or service** – no one can be all things to all people, so having a defined, repeatable product will help people understand what it is you are 'selling'.
2. **Identifying your target market** – for example, are you targeting larger Merino producers in the high rainfall zone, or the sheep industry generally?
3. **Knowing your competition** – this can include competition you have generated for yourself, for example, an earlier version of research that is now a competing message in the market.
4. **Developing awareness** – people need to know you or the company you are distributing information on behalf of (as well as the information itself) exists. Research shows potential customers (i.e., clients) must be exposed to something 5 to 15 times before they are likely to think of it when an appropriate situation arises.
5. **Building credibility** – you must demonstrate knowledge, experience, and a positive association without appearing over-the-top in trying to prove how knowledgeable and

experienced you are. It's also important to remember the impact your association with brands or organisations has on your credibility. There's often the impression of bias if you're aligned with a commercial company (whether real or perceived) and anyone you work with basically becomes an extension of you.

6. **Consistency** – in the information you are distributing and how you conduct business. This ranges from the look of the information to the level and tone in which it is presented, to your clothing, to the message you deliver and the service you provide.
7. **Trust** – in your brand and what you are selling, and who you choose to sell it for you.
8. **Focus** – on how and what you are providing to ensure what you're selling is clearly understood by your potential clients and your efforts are being focused where they will return benefit to you and your client.

When communicating, it is essential to remember your target market – you should be communicating in a style that works for the people you want to accept the information, not as you would like to receive it. For example, it is rare that non-scientists appreciate the value of a full scientific research report, they more commonly value someone who can take that information and provide the relevant outcomes to the audience they are presenting it to, using appropriate mediums and language style.

People are unlikely to adopt a new technique unless they feel confident in making the change and aware of the likely implications this will have on their business. The most important thing to know is that you need the person to change, not the business, and therefore the motivating factors and value proposition for the change need to be geared towards a person with emotions and experiences which guide their decision making, rather than a straightforward reasoning based solely on scientific recommendations or economics.

How can we more effectively extend R&D for on-farm adoption?

- Simplicity: the simpler the message, the clearer it is to communicate and the less chance you have of it becoming misconstrued during delivery or implementation.
- Mixed medium: no one method best suits all people, so it's essential to use different methods of communicating the same message. This is also important in raising awareness and building confidence in the message.
- Timing is everything: delivering a message at the time of year it's relevant is crucial because farming is a complex business in which a lot of things are happening all year around, meaning that people are focused on the task at hand.
- Industry consensus: nothing frustrates farmers more than hearing conflicting industry messages and recommendations. Unless there's a very good reason for challenging an industry message, it's more effective to deliver that and add to it with regional knowledge and practical tips and tricks for implementation.
- Use of grower advocates: this can be presenting in conjunction with a 'technical expert', as a case study, in an interview – the list goes on! Basically, people want to identify with people they know understand them and they feel familiarity with.
- Information flow both up and down the chain: it's usual to think of extension and adoption as something that comes from research and is then applied on-ground, but there are many examples of farmers innovating and doing their own research on-farm that R&D can learn from, so two-way communication is essential to avoid missing the practical application.
- Less linear, more lateral: in life there are very few straight lines, so our extension and adoption processes must also be flexible and dynamic, allowing people to jump on and off wherever suits them.

- Remember what success is: whilst the ultimate outcome for some may be to have everyone following 'best practice', it's crucial to remember that a farm is someone's business and they can choose to do, or not to do, whatever they like, so even partial implementation of a new technique is a win.

What extension opportunities does AWI have?

Australian Wool Innovation invests in research, development, extension and marketing across the global wool supply chain.

Several of AWI's key extension investments are highlighted below:

- **Lifetime Ewe Management** is AWI's flagship reproduction investment that is delivered by Rural Industry Skills Training (RIST), based in Hamilton, Victoria. This relationship is decades old and the Lifetime Ewe Management (LTEM) formula for group-based, peer-to-peer learning has stood the test of time.
  The 12-month course which is delivered in six, hands on, on-farm sessions, has attracted over 4,300 woolgrowers, and on average, participants increased their whole-farm stocking rate by 9.3%, increased lamb-marking percentage by 7% and reduced ewe mortality from 4.1 to 3.0%. AWI has recently committed to a new 3-year contract with RIST to continue LTEM subsidy support through to 2023.
  www.wool.com/LTEM

- AWI's **Picking Performer Ewes** (PPE) workshop is designed for woolgrowers aiming to lift the lifetime performance of their Merino ewes. PPE identifies key practical actions for commercial enterprises to implement on-farm to achieve this performance aim.
  PPE assists the commercial self-replacing Merino production sector in recognising and placing appropriate importance on the total lifetime productivity potential and value of their Merino ewes (fleece, meat and surplus stock) and aims to achieve a minimum weaning rate of 95% from Merino joinings.
  PPE complements the AWI-funded Lifetime Ewe Management (LTEM) course and is ideal as an LTEM refresher but also for those who haven't completed LTEM yet. PPE is one of AWI's one-day workshops which are all 100% standalone yet 100% complementary.
  www.wool.com/PPE

- **RAMping Up Repro** is an AWI and Zoetis co-owned, practical, one-day workshop. The focus of RAMping Up Repro (RUR) is improving ram performance and the working longevity in commercial sheep enterprises, increasing the skill of producers across the key components of ram performance and impacts on overall breeding enterprise performance.
  Each participant is guided through a thorough pre-joining ram inspection by an accredited deliverer and given the opportunity to increase their practical skills to undertake this in their own operation. The workshop is designed to give attendees the confidence to incorporate these skills into their own routine management, thus improving the performance of their rams.
  www.wool.com/RUR

- AWI's **Winning With Weaners** (WWW) one-day workshop is aimed at lifting the lifetime performance from Merino ewes through improved management of weaners. WWW assists participants in understanding the key issues affecting weaner survival and performance and guides them through developing targets for growth for this key cohort of sheep.

The workshops discuss factors that contribute to weaner mortality and illthrift and provides practical pathways for improving lifetime performance. Participants gain an understanding of the impact of weaning weight on the survival of weaners to first joining; weaner nutrition - both energy and protein; the importance of weaner management on lifetime performance of breeding ewes; and strategies for success – mapping it all out in a management calendar.

www.wool.com/WWW

- AWI funds **AWI State Grower Extension Networks** in each wool-growing state of Australia. The Networks each has a Producer Advisory Panel (PAP) to report what is happening on-ground in their region and to assist in setting the strategic priorities for their state. The Networks are AWI's key extension delivery platform and rollout AWI's one day workshops as well as other extension events that are identified by the PAP for their state, partner with other industry groups to support their extension events and deliver key production or disaster information in a timely way.

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Hypocalcaemia – cases, causes and what to do about it?

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Introduction

Hypocalcaemia is a well-recognised syndrome in Australia, and also around the globe[1,2]. It has been identified to cause mortality risk to sheep that have been fed grain diets for prolonged periods[3]. It has also been a cause of pre-and post-lambing mortality in ewes in southern Australia, in particular. Pre-lambing mortality is a well-recognised syndrome associated with yarding ewes in the last 3 weeks (can be up to 6 weeks) prior to lambing or soon after lambing and is caused by calcium (Ca) levels falling precipitously low when ewes have been off feed for too long. Typically, ewes are more affected in years when pastures are short as dry matter intake is reduced and hence Ca intake is low. Further, older twin-bearing ewes have been most at risk.

In recent years, an increased mortality rate of ewes grazing lush, productive pastures has been observed by the author. Further, Ag Vic report that advisers, veterinarians and producer group coordinators across Victoria participating in a discussion on mineral imbalances in sheep, indicated that hypocalcaemia is an increasing issue in Victoria (pers comm Jane Court). They also report an increase in dystocia and "downer ewes". Reduced lamb growth rates, abnormal skeletal (including dental) development and fragile bones that tend to break have also been reported.

This is hypothesised to be due to a changing sheep industry increasing the hypocalcaemic risk for ewes in southern temperate Australia. The key factors behind this increased risk is hypothesised to be increasing calcium demands from higher reproductive rates and faster growing sheep. At the same time, profit-driven farms are sowing modern pasture cultivars and fertilising them optimally, which results in increased dry matter production, higher pasture quality and pastures that are generally lusher and travel through the digestive system faster due to high digestibility. Low Vitamin D levels impacts even further on Ca homeostasis.

Given there is a continuing trend for farmers to improve the farm's pasture base, and to run sheep with higher growth potential and reproductive rates, one could also hypothesise that hypocalcaemia might affect flocks more widely in the future.

Treatment of hypocalcaemia is not always successful, hence there is an economic and animal welfare imperative to implement effective prevention programs. It is unfortunate that a lack of peer-reviewed science in sheep impacts on our ability to recommend evidence based veterinary science but there is a pressing need to prevent welfare impacts. The aim of this paper is to highlight why it is hypothesised that hypocalcaemia risk has been increasing, why it may get worse and how this syndrome might be prevented.

Calcium metabolism essentials

Hypocalcaemic risk is well known in the past and the mechanisms behind hypocalcaemic risk has been described well previously[1,4]. In this section, essential components of calcium metabolism are outlined. Calcium metabolism is complex, see Figure 1, with calcium metabolism and homeostasis under the influence of parathyroid hormone, calcitonin and Vitamin D.

For southern temperate Australia south of the 34th parallel (approximately south of a line between Margaret River and Sydney), Vitamin D levels have been found to be low,

particularly further south, with very low levels found in southern Victoria and responses to Vitamin D supplementation of young sheep in Tasmania[5,6]. Indeed, some ewes and lambs in each flock sampled in southern Victoria had no detectable levels of Vitamin D.
Further to these impacts on calcium homeostasis is the influences of various other minerals and dietary factors not outlined in Figure 1.

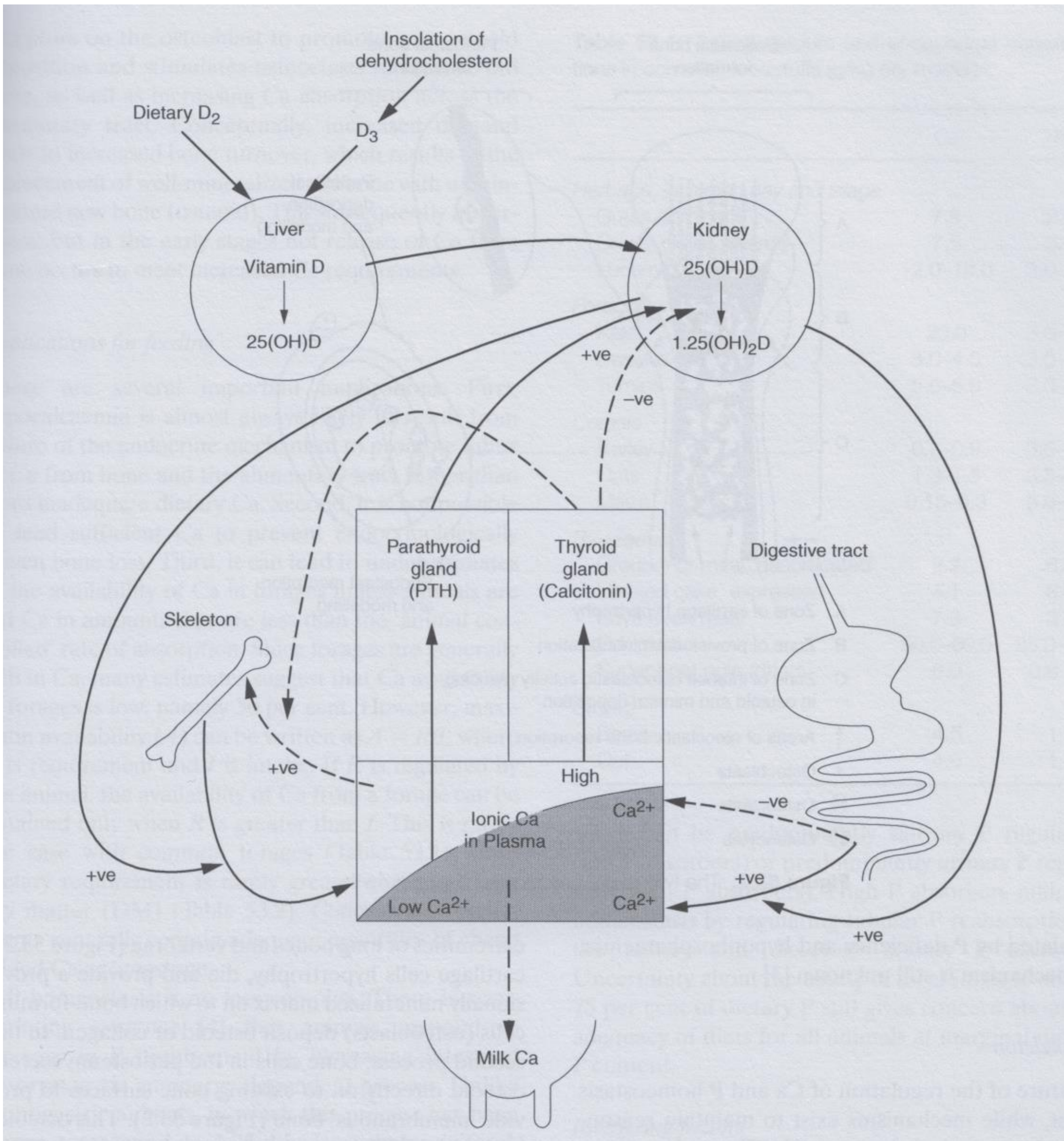

Figure 1: A schematic representation of factors influencing calcium metabolism in the ewe[2]

Magnesium (Mg) has an important role in aiding calcium absorption from the gastrointestinal tract. Thus, if sources of Ca are being added to the diet, then providing adequate Mg is also necessary. For instance, outside of optimum Mg blood plasma concentrations, skeletal Ca resorption is reduced by up to 50%, while increasing dietary Mg has been demonstrated to increase Ca absorption from the ovine small intestine[2]. Further, 1,23-dihydroxycholecalciferol and parathyroid hormone activity are also dependent on plasma Mg concentration.
Other minerals also can have a profound impact on Ca homeostasis including phosphate, sodium, and potassium. There are also other minerals that can have a minor impact on Ca homeostasis.
While phosphate is important in ruminant diets, ideally Ca should be maintained at 2:1 Ca:P ratio, but a range of 1:1 to 7:1 is considered acceptable. Grain feeding is an obvious hypocalcaemic risk as cereals are typically 0.25:1 and legume grains are usually not much

better than 0.5:1 Ca:P ratio[7]. Clearly, prolonged feeding of grains results in decreased Ca plasma levels, making the ewe more prone to clinical hypocalcaemia. Thus, the standard recommendation is to feed 1.5% finely ground lime with grain fed out.

Pasture can also have a low Ca:P ratio. This may be due to high phosphate levels. This has been a characteristic of some southern Victorian and Tasmanian pastures that the author has tested in recent years. More detail is presented in the section outlining case studies. However, it is important to note, that if the pasture has a low Ca:P ratio, then the whole diet has a low Ca:P ratio and that this will be the case for a large part of the year subsequent to the autumn break in southern temperate Australia.

High dietary cation-anion difference (DCAD) also has a role in affecting Ca and Mg homeostasis adversely. DCAD is measured by taking the sum of chlorine and sulphur away from the sum of sodium and potassium milli-equivalents to derive a figure that is expressed in mEq/kg DM. In the case of pasture that has a high DCAD reading, the surplus of cations results in a metabolic alkalosis, which reduces the ability to release Ca from bone reserves. Conversely, an anionic diet results in an increased absorption of Ca, release of Ca from bones and hence higher plasma Ca levels. This is what occurred in a trial treating ewes a control diet, a fixed anion excess diet and a fixed cation excess diet. This has also been observed in cattle and goats[8]. If a high DCAD pasture is the only diet that a spring lambing ewe eats from after an autumn break in April to lambing in September, Ca homeostasis will be difficult, particularly if she is in southern temperate Australia with low Vitamin D levels. Of course, pasture with high potassium levels in pasture will decrease Ca and Mg plasma levels due to the impact on the acid-base balance of the rumen, which in turn will affect the acid-base balance of blood. This includes pastures recently top-dressed with muriate of potash or other fertiliser mixes with high potassium content. Nevertheless, the case study farms were not using potash fertiliser regularly and still had very high potassium levels in their pasture.

Given a ewe mobilises about 20% of her bone Ca during pregnancy and lactation, she needs to replenish this Ca post lactation[4]. Normally, this occurs within a month of ending lactation, but if the feed source doesn't allow that effectively, then her Ca reserves will tend to decrease more than usual over her life as each lactation draws down on her reserves.

As ewes age they are less able to mobilise Ca and also have reduced ability to absorb Ca from their diet. This particularly applies to ewes 5 years of age and older. In older ewes this can also be exacerbated by increased likelihood of carrying twin lambs. The additional Ca requirement of twin lambs puts even more pressure on Ca blood levels as the majority of skeletal formation occurs in the last 6 weeks of pregnancy.

The fibre content of the feed also affects Ca homeostasis. This is because saliva is rich in bicarbonate, offsetting the impact of a cationic diet. This is dependent on chewing activity and with less lush, less digestible pastures there will be more chewing and more saliva. Hence more bicarbonate to help mobilise more Ca from bone. Classic hypocalcaemia occurs on short pastures in winter with little dry feed left over from the previous season. In contrast, modern well-fertilised pastures have very little dry feed standing in winter as they are better utilised due to ease of running a higher stocking rate on them and the pasture being more digestible is consumed earlier.

Provision of straw or hay may aid chewing behaviour, hence reduce the hypocalcaemic risk. As hypothesised by Grant et al, in 1992, "dietary factors affecting salivation may also affect acid-base balance and be more important than Ca intake in influencing Ca metabolism in grazing sheep"[8]. All the case study farms had adequate dietary Ca.

Ca reserves in bone, can potentially be built up again after lambing for two reasons. Firstly, as pastures mature, Ca:P ratio returns to acceptable levels[20]. Secondly, after lambing the ewe intestinal tract is able to absorb Ca four times more efficiently than in late pregnancy[4].

Some plants impact on Ca homeostasis by anti-Vitamin D activity, including kale, Italian ryegrass, cereals grazed in winter, as well as weeds such as *Oxalis spp*, sorrel (*Rumex spp*) and Fat Hen (*Chenopodium*)[1].

Much of the focus on hypocalcaemia in the past has been on the clinical expression of the disease[9]. However, it is clear that there is a potential iceberg of subclinical hypocalcaemia that needs to be addressed to reduced mortality risk of ewes and potentially improve lamb

survival and growth rates[10]. For instance, Mg is a neuroprotectant and has other features that might be expected if Mg is low to impact on lamb survival. Likewise, Ca is required for smooth muscle function, and hence if low will impact on uterine function and possibly, lamb survival from difficult parturition.
There is evidence of sub clinical hypocalcaemia and lifetime Ca levels reducing over time in the dairy cow, due to a combination of low DCAD pastures, low Vitamin D and a low Ca:P ratio of their diet[8]. There is evidence in the dairy cow of a combined preventative approach of a negative DCAD diet and Vitamin D supplementation resulting in high Ca plasma levels and a decrease in subclinical hypocalcaemic disorders[9].
Although ewes are not little dairy cows, the author contends that this is logically occurring also in the ewe due to the greater incidence of clinical hypocalcaemia in older ewes. Thus, over their lifetime Ca reserves keep depleting and never fully recover post lambing and over summer before being joined again.

Why hypocalcaemia appears to be getting worse?

Over the last 25 years there have been two key developments that have in all likelihood increased Ca demand by the ewe.
Firstly, genetic progress for prime lamb genetics have focused on improving growth rate and reproductive rates. Both characteristics are likely to increase Ca demand of the ewe. For example, see the following tables outlining genetic gain across the industry in recent years[11]. Thus, over the last 9 years, the ASBV gain in Lambplan's Maternal Post Weaning Weight (PWT) is about 3.3 kg. At the same time the Number of Lambs Weaned (NLW) has increased by 4%. These genetic gains will result in a significant increase in Ca demand.

<u>LAMBPLAN – Maternal ASBV Genetic Trends</u>

Post weaning weight (PWT)	
Year	*LAMBPLAN-Maternal breeds*
2010	7.35
2011	7.87
2012	8.36
2013	8.66
2014	9.22
2015	9.59
2016	9.97
2017	10.27
2018	10.58
2019	10.64

Number of lambs weaned (NLW)	
Year	*LAMBPLAN-Maternal breeds*
2010	2%
2011	2%
2012	3%
2013	3%
2014	3%
2015	4%
2016	4%
2017	5%
2018	6%
2019	6%

<u>MERINOSELECT ASBV Genetic Trends</u>

Post weaning weight (PWT)	
Year	*MERINOSELECT*
2010	1.35
2011	1.51
2012	1.63
2013	1.79
2014	1.97
2015	2.23
2016	2.42
2017	2.79
2018	2.93
2019	3.33

Secondly, in addition to the trends outlined above, there has been a general trend in the Australian sheep industry to move to either maternal prime lamb genetics with intrinsically higher reproductive and growth rates or move to Merino genetics that also have higher growth and reproductive rates. Again, the likely outcome of this change is for ewe calcium demand will be higher than it was 25 years ago.

At the same time many pastures in southern temperate Australia have received more fertiliser, particularly phosphate-based fertilisers and some have also been renovated with newer, more productive pasture cultivars. Thus, instead of ewes grazing "Glenthompson ryegrass" (Onion grass) 25 years ago, they are grazing improved pastures that are lusher and more productive.

This is not a disease of the average farmer. It is a disease of Merino and maternal prime lamb ewes grazing high quality, lush pastures in winter with high growth and reproduction genetics. It is exactly the type of enterprise recommended by many farm advisers.

Thus, ewes that have higher Ca requirements are grazing pastures with high DCAD, very low Ca:P ratios, and low Vit D, which results in limiting their Ca uptake and Ca mobilisation from bones[8].

This is probably why some high-performance farmers have been reporting high mortality rates around lambing despite being at target condition score and pasture Food On Offer (FOO) levels according to Lifetime Ewe guidelines[12]. The ewes on these farms are not thin and are on at least target pasture FOO levels during late pregnancy and during lactation.

A characteristic of the higher mortality rates being experienced include higher dystocia rates and downer ewes. Additionally, sudden deaths have been occurring later in the spring after lambing when ewes have been yarded for marking or weaning in October. Pastures sampled and tested at the time with full wet chemistry analysis suggested that they were conducive for hypocalcaemia due to low Ca:P ratio and high DCAD levels. Pathology results supported the diagnosis of hypocalcaemia as the cause of the sudden death.

It is quite logical to speculate that some of the key sheep industry trends that are driving the worsening risk of hypocalcaemia in southern temperate Australia, are likely to continue to put pressure on ewe Ca supply and demand in the future. That is, it is likely for the trend to select for higher growth and reproductive rates to continue. Further, sheep industry profitability is underpinning a lot of pasture improvement and higher fertiliser application rates, leading to more productive pastures with higher digestibility and lushness. As more farms adopt these genetics and pastures, following the early adopters of the industry, hypocalcaemia could be a greater risk to ewe health and welfare in the future.

Thus, this hypocalcaemic syndrome is disease of "good" sheep management, given sheep, lamb and wool commodity prices over the last 15 years.

Diagnosing hypocalcaemic risk

Diagnosis of hypocalcaemia has traditionally relied on history, presenting clinical signs, blood pathology and rapid response to treatment. However, in many cases there can be a mixture of hypocalcaemia and ketosis affecting ewes. If hypocalcaemia is preventing a ewe from eating due to being immobilised, then it can also succumb to ketosis as she cannot eat.

Blood testing in live sheep can be undertaken. Post-mortem changes to blood chemistry are rapid, meaning that accurate diagnosis cannot be made. Eye aqueous humour sampling can be made after death and can be diagnostic with knowledge of the likely post-mortem period.

The typical clinical presentation of hypocalcaemia is of an animal unable to move, but aware of her surroundings sitting up on her haunches. In contrast, ewes affected by ketosis are not aware of their surroundings, typically recumbent (though in early stages are standing) and are also unable to move. Further, treatment with calcium borogluconate usually results in a rapid recovery from hypocalcaemia, albeit multiple treatments may be required. In contrast, ketotic ewes suffering pregnancy toxaemia, usually don't respond to treatment.

However, none of these methods forewarn adequately, apart from possibly blood testing ewes, of the risk of a hypocalcaemic event. Blood testing is generally expensive as it requires a farm visit by a veterinarian and laboratory charges. Further, yarding may precipitate hypocalcaemia in susceptible ewes.

Testing pastures after the autumn break once they are established and vegetative for nutritive value via wet chemistry analysis can provide a full mineral analysis and determination of the Ca:P ratio, mineral interactions with Mg and Ca and in addition, the pasture DCAD level. Thus, in combination with a risk assessment of the ewe, a full hypocalcaemia risk can be made. There are a number of these type of assessments described in the literature of this approach[1,13]. Nevertheless, there is a paucity of science establishing that this is diagnostic in sheep. Nevertheless, the approach is logical and has been used reasonably frequently in the field.

Thus, it is recommended to test pasture during mid pregnancy to assess the DCAD and mineral balance of the diet. The decision to intervene with preventative measures depends on a risk assessment: -

- DCAD >300 mEq/kg DM – may be lower[12,14]
- Ca:P ratio < 1:1
- Low Mg < 0.9 g/kg DM
- High potassium > 5g/kg DM
- Ewe age of 5 years and older
- Ewe is carrying multiple lambs
- Pasture is highly digestible and lush (>75% digestibility)
- Little standing dry feed in the paddock derived from the previous year
- The ewes are situated south of the Murray River (including Tasmania), as Vit D is also likely to be very low
- Prolonged feeding of grain for over 6 weeks without a limestone supplement.

This risk assessment has seemed to work well to reduce hypocalcaemic deaths in flocks the author has worked with, although there is an absence of trials to support this assessment. This assessment has a heavy reliance on pasture testing but there has been good agreement between the mineral status of ewes and the mineral composition of the forage they are on, which is to be expected[15].

There is little debate in regard to the hypocalcaemic risk of feeding for more than 6 weeks of grains with a Ca:P ratio of less than 1:1[1]. Logically, then there should be also be little debate about the risk of ewes being fed a sole diet of pasture for at least 3 months before lambing in southern temperate Australia, also with a Ca:P ratio less than 1:1.

Subclinical hypocalcaemia may be a bigger issue than previously understood. There is evidence that hypocalcaemia results in uterine inertia, that contributes to dystocia as Ca is a trigger for myometrial contractions[16]. Other complications include retained placenta and uterine prolapse in dairy cattle and there are other syndromes such as osteoporosis in older dairy cows that is postulated as being due to subclinical hypocalcaemia[9]. Uterine prolapse has been observed in affected ewe flocks by the author, but there is little evidence in the literature to support this statement, but there is evidence from experimental work that there is a likely relationship between Ca and dystocia in sheep[10].

Further, there is evidence in the field that subclinical hypocalcaemia was associated with decreased lamb survival. Ca may also be involved with non-shivering thermogenesis and thermoregulation of lambs soon after birth[10]. The author has also observed a number of ewes on affected farms presenting with a prolapsed uterus. A recent study of ewe mortality found a number of ewes in WA autopsied had grass in their rumen and presenting with a ruptured uterus without any other cause of death (pers comm Caroline Jacobson). It is also possible that hypocalcaemia reduces rumen and abomasal motility, which also may precipitate pregnancy toxaemia. A recent survey of pre-lambing blood and urine samples found a significant number of ewes in southern Australia may be at risk of subclinical hypocalcaemia and hypomagnesaemia[17].

Preventing hypocalcaemia

There is a general acceptance that feeding cereal grain for prolonged periods, particularly in a drought, presents hypocalcaemic risk for sheep, particularly ewes[3]. And generally, it is accepted to add 1.5% finely ground limestone to the grain when feeding grain to prevent hypocalcaemic risk.

Apart from immediately relieving clinical signs as outlined previously with calcium borogluconate, it is generally recommended to give some access to hay or straw to encourage Ca absorption to prevent the emergence of further clinical cases. Unimix® is an oral mix available from the Mackinnon Project, which provides ewes with Ca for a longer period than calcium borogluconate treatment.

Providing a calcium supplement prior to lambing is favoured by many advising in the sheep industry. While the actual formulation may vary, the basis is to provide high levels of calcium, magnesium and sodium, and with the latter in the form of common salt, that also results in the supplement being more palatable.

An example is the standard industry supplement outlined as 40% Causmag (MgO): 40% limestone ($CaCO_3$): 20% salt (NaCl)[18]. These type of lick supplements can be made up easily enough by the farmer and are relatively cheap. However, given that they are usually put out during winter when ewes are close to lambing, they inevitably get wet. This means that they need to be frequently changed, as once wet, the leaching of salt means that they are less palatable, and hence ewe intake of the lick could well below effective therapeutic levels if not refreshed. There are commercial licks available with a formulation along the same lines, but many of these have too little magnesium, hence may result in inadequate Ca absorption.

Weatherproofing lick supplements mean that they can be safely left out in the paddock and are available for livestock consumption. Although this process leads to an increase in cost, this results in a more reliable way to supplement livestock. The additional cost can be justified if there are savings in labour and the supplement actually is eaten regularly by the stock.

However, there are further issues with the standard licks. Most ewes in southern Australia, as outlined previously, are likely to have very low Vitamin D levels, and this is not being addressed. Further, all the case studies outlined later in this paper, did not have dietary Ca levels, and the author is yet to see this on client farms. It is hypothesised that at least high Mg, anionic preparations and Vitamin D are required to address ewe Ca homeostasis adequately.

The recent availability of calcidiol, a precursor of $1{,}25(OH)_2D_3$ (Vitamin D) which is sold commercially by DSM as Hy-D®, has shown to be effective as part of a lick supplement to improve Ca levels, mainly in dairy cattle[9], but also in beef steers[19]. There was also some success with the calcidiol treatment with sheep to increase plasma Ca, but there were some poorer results at higher inclusions rates of calcidiol[20]. In one of the experiments reported, lambs were also heavier through to weaning.

The previous concerns raised about diet DCAD on lush pastures is also not being addressed adequately with the "standard" supplements. Yet, as already outlined, there is strong evidence that this can aid calcium homeostasis.

Thus, the recent introduction of a weatherproof lick supplement that reduces the DCAD of the total diet, has appropriate levels of Ca and Mg and has an effective Vitamin D precursor in the form of calcidiol (Bayer StayDry Hy-Cal®), based on the evidence accumulated previously, should achieve effective improvements in Ca homeostasis for the late pregnant ewe. There is a requirement for trials to demonstrate the full effectiveness of this approach, but there is sufficient evidence to suggest that it should be highly effective to prevent hypocalcaemia in ewes.

In the long term, it has been suggested by some that liming pastures should have an impact on pasture DCAD in the long term. Indeed, in a glasshouse experiment five different grasses limed and grown in pots resulted in low DCAD due to increased uptake of Ca and decreased uptake of K and Cl[21]. Confirmation of this in the field would seem to be a high priority, given the prospects of high DCAD pastures becoming more widespread. However, the author's experience does not match these glasshouse experimental results. Nevertheless, from first principles, this approach would be logical to pursue. And it is something that should be a research priority to confirm that this works in field trials, as it provides hope going forward for a more cost-effective solution.

Is this increase in cost for an average farm by addressing Ca metabolism of ewes likely to be profitable? Examining this using indicative commodity prices over the last 5 years: -

- Bayer StayDry Hi-Cal for 3 months might cost $4/ewe
- For a prime lamb operation, based on $8.00/kg dressed for lamb, 7% selling costs, $250/ewe store value, $17/ewe net fleece value and 150% marking
  - Break-even is 0.7% ewe mortality reduction and 100% return on investment is 1.4% mortality reduction
- A Merino operation with $75/ewe fleece value, 80% lambs marked and a value of $125/lamb
  - Break-even is 1.2% ewe mortality reduction and 100% return on investment is 2.4% mortality reduction

Animal welfare

Clearly, the ewe mortality risk inherent in hypocalcaemia is a serious animal welfare issue that needs to be addressed. There is enough evidence to suggest that Ca levels are very low in southern Australian flocks and thus it is an industry issue that should not continue. Subclinical impacts are also a concern, due to potential impacts on welfare, such as predisposing ewes to pregnancy toxaemia and affecting lamb survival and growth. This warrants further research.

In conclusion, these concerns should make this disease a funding priority for rural research and development organisations.

Case studies

Case Number 1: Some salient findings from the case study farms are presented below. These are not the only farms that the author has been working with, but some with better records.

The first farm had a syndrome, which by process of elimination, is explained best by Secondary Nutritional Hyperparathyroidism (SNHP)[22]. Some of the key findings were: -

- Long growing season western Victorian farm on basalt soil types with 720 mm rainfall
- Extensive pasture improvement program with new productive cultivars and soil Olsen P levels mostly > 18 ppm
- Typical soil pH (CaCl) = 5.0
- Stocking rate was 30 dse/ha based on farm benchmarking results
- Considerable levels of osteoporosis (confirmed by pathology) with higher and higher culling of ewes due to premature teeth wear and lost productivity. In 2012/13, 38% of 4/5 yo ewes were culled
- Because of lower bodyweights, scanning percentages started to decline, along with lambing percentage and poorer lamb growth rates up to the finishing stage
- Copper levels were adequate for both blood and liver. Bloods were checked several times and were adequate, while liver results averaged 0.56 mmol/kg wet weight, with low level <0.23 mmol/kg
- Pasture test taken July 2013 of pasture mix of ryegrass and sub clover
  - DCAD 438 meq/kg DM
  - Calcium 5 g/kg DM = within recommended range[23]
  - Phosphorus 4.6 g/kg DM > upper recommended range of 3.0 g/kg
  - Ca:P ratio = 1.1:1 < recommended lower range of 1:1
  - Magnesium 2.7 g/kg DM > upper recommended range of 1.2 g/kg
  - Potassium 30 g/kg DM = 6 x upper recommended range of 5.0 g/kg
  - Chloride 17.3 g/kg DM > upper recommended range of 1.0 g/kg
  - Sodium 9.4 g/kg DM > upper recommended range of 1.0 g/kg
  - Digestibility = not presented
  - ME = 11.5 MJ/kg DM
  - Crude protein = 30.8%

Clearly, high DCAD, high P, very high chloride and potassium and low Ca:P ratio would have made Ca homeostasis difficult along with inevitable low Vit D levels. There were other pasture feed tests that had a 0.5:1 Ca:P ratio. As a consequence, there were numerous devastating outcomes for this farm from calcium metabolism issues. This was not due to copper deficiency.

Case Number 2: Predominantly maternal composite prime lamb flock situated in medium rainfall Upper Derwent Valley, Tasmania. Also, significant area irrigated and cropped. Author was approached to help due to high ewe mortality rates around lambing.

- Stocking rate of over 15 dse/ha and lamb marking >140% regularly
- Rainfall 542 mm winter dominant on dryland
- Extensive pasture improvement program with new productive cultivars and soil Olsen P levels mostly > 18 ppm
- Typical soil pH (CaCl) = 6.10
- Pasture test taken July 2014 of fresh ryegrass
    - DCAD 229 meq/kg DM
    - Calcium 2.3 g/kg DM = within recommended range
    - Phosphorus 4.8 g/kg DM > upper recommended range of 3.0 g/kg
    - Ca:P ratio = 0.5:1 < recommended lower range of 1:1
    - Magnesium 2.0 g/kg DM > upper recommended range of 1.2 g/kg
    - Potassium 28 g/kg DM = 5.5 x upper recommended range of 5.0 g/kg
    - Chloride 17.1 g/kg DM > upper recommended range of 1.0 g/kg
    - Sodium 4.6 g/kg DM > upper recommended range of 1.0 g/kg
    - Sulphur 3.3 g/kg DM > upper recommended range of 2.0 g/kg
    - Digestibility = 80.1%
    - ME = 13.3 MJ/kg DM
    - Crude protein = 28.8%
- Ewe mortality rate before supplementation started was on the higher end of normal, estimated at 6%, but well over 10% in older twin mobs.
- Ewe mortality rate post CRU Sheep Lick 2.1%

Case Number 3: Mixed grazing cropping farm at Lake Bolac with predominantly basalt over limestone soil types. Owner recognised that ewe death rates had been high over recent years, but due to scale of operation had not been looked into properly until the author was engaged to advise on animal health and productivity of the sheep enterprise.

- Stocking rate of about 17 dse/ha and lamb marking >100-120% regularly in Merinos and >140% in prime lamb composites
- Rainfall 538 mm winter dominant
- After cropping phase new productive perennial and medium term ryegrass cultivars and sub clover sown with soil Olsen P levels mostly > 18 ppm
- A lot of lime at been applied on the farm due to the cropping program and generally pH > 5.5 in CaCl
- Pasture test taken June 2017 of fresh ryegrass/clover pasture
    - DCAD 144 meq/kg DM
    - Calcium 2.4 g/kg DM = within recommended range
    - Phosphorus 3.7 g/kg DM > upper recommended range of 3.0 g/kg
    - Ca:P ratio = 0.6:1 < recommended lower range of 1:1
    - Magnesium 2.3 g/kg DM > upper recommended range of 1.2 g/kg
    - Potassium 27.9 g/kg DM = 5.5 x upper recommended range of 5.0 g/kg
    - Chloride 18.4 g/kg DM > upper recommended range of 1.0 g/kg
    - Sodium 3.0 g/kg DM > upper recommended range of 1.0 g/kg
    - Sulphur 2.9 g/kg DM > upper recommended range of 2.0 g/kg
    - Digestibility = 72%
    - ME = 10.3 MJ/kg DM
    - Crude protein = 21%
- Records on the sheep enterprise were a bit sketchy sometimes, but on regular farm visits during lambing there was plenty of evidence of downer ewes and a lot of

calcium borogluconate being used. Owner frequently stated that he thought ewe mortality rate before supplementation started was closer to 10%. This may have been exacerbated by the flock age profile being weighted to aged ewes with most carrying twins.

- Ewe mortality rate post CRU Sheep Lick stated to be closer to 2%
  - On farm visits during lambing, downer ewes were not viewed and calcium borogluconate usage had all but ceased
  - So had sales of Buccalgesic to the farm to aid downer ewes

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Bacterial Arthritis in Lambs

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Introduction

Bacterial arthritis in sheep is a painful and debilitating condition that is widespread across all sheep-raising regions and climatic zones of Australia. The condition is a welfare issue when affected sheep are held on-farm before being culled. Three main groups of bacteria have been implicated in arthritis in Australian sheep, *Erysipelothrix rhusiopathiae*, *Chlamydia pecorum* and a range of pyogenic bacteria.

This paper discusses recent research on the economic cost of arthritis in Australian lambs, as well as recent international findings on *Erysipelothrix rhusiopathiae* and *Streptococcus dysgalactiae* subspecies *dysgalactiae* infection in lambs.

Economic cost of arthritis in Australian lambs

At slaughter, bacterial arthritis in sheep causes economic losses through the condemnation of all or parts of the carcass, as specified in the Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption. On-farm it can lead to the death or the culling of affected animals, as well as substantially delaying the turn-off time of affected lambs.[1]

The economic cost of arthritis was investigated in lambs presenting to an abattoir in southern Australia using a combination of the prevalence of arthritis detected during meat inspection, condemnation rates, trim weight and carcass weight, and fat measurements.[2] Data were collected on 354 lines of lambs representing 63,287 carcasses. One hundred and sixty-nine consignments, or approximately one-half of the consignments, had at least one carcass with arthritis/polyarthritis detected by meat inspection personnel. Four hundred and twenty-two, or 0.7%, of the carcasses had arthritis/polyarthritis in at least one joint. When arthritis was present, on average 2.0% of the line was affected. Three carcasses with arthritis were condemned and the remainder trimmed, with an average trim weight of 0.7 kg. In addition, arthritis reduced the growth of lambs by 1.2 kg hot standard carcass weight, approximately 2.7 kg liveweight (assuming 45% dressing percentage) and reduced fat cover by 1.8 mm.

Recently, arthritis was estimated to cost the Australian sheep industry $39 million annually, based on a range of factors, including a carcass condemnation rate of 0.018% with 0.07% of carcasses trimmed.[3] The results discussed above indicate that this estimate may be conservative. Although the Export Production and Condemnation Statistics database indicates that ~0.02% of lamb carcasses are condemned for bacterial arthritis in Australia annually. The new research results suggest that for every carcass condemned for arthritis, another 140 will be trimmed, or a carcass trim rate of 2.8%, 40-fold higher than that used in the earlier estimate of the cost of arthritis to the Australian sheep industry. The results also suggest that in one-half of Australia's sheep flocks, lambs develop bacterial

arthritis during their first few months of life. This high prevalence of bacterial joint infections is likely to contribute to weaner loss, which is a significant economic issue for the

Australian sheep industry, with on average 17% of Merino weaners dying annually.[3] The Sheep CRC Information Nucleus Flock trial across eight sites over 4 years

using Merino, Maternal and Terminal breeds found that lamb loss from 3 days after birth to weaning was on average 21 ± 7%, ranging from 9 to 34%.[4] The survival of Merino weaner sheep was studied over several years on a wool-growing property in western Victoria and revealed a strong association between survival and weaning weight, and survival and growth rate, with both lighter lambs at weaning reported, as well as that lambs with low growth rates were at increased risk of mortality.[5] A study of survival of weaned Merino sheep on properties on the southern and central Tablelands of New South Wales reported a similar result, with the lightest quartile of lambs twice as likely to die in the 6 months following weaning than heavier lambs.[6] I and others have previously reported that Merino lambs are at increased risk of bacterial joint infections,[7, 8] and that husbandry procedures that reduce the growth rate of lambs lead to reduced weaner survival.[9]

Erysipelothrix rhusiopathiae

E. rhusiopathiae is a Gram-positive bacterium that is widespread and able to survive for a long time in the environment, including marine environments, as well being a pathogen or a commensal in a wide variety of wild and domestic animals, birds and fish.[10] Globally, and in Australia, *E. rhusiopathiae* is the most common cause of bacterial polyarthritis in lambs.[7, 11, 12]

Disease caused by *E. rhusiopathiae* in sheep was studied during an outbreak in a Norwegian Spæl sheep flock.[13] In the acute phase of the disease, 48 of 230 (20%) lambs developed clinical signs and four died (1.7%). One acute case was necropsied and *E. rhusiopathiae* was cultured from all major organs investigated and from joints. Sixteen of the diseased animals (33%) developed a chronic polyarthritis and eight of these lambs were sacrificed for post-mortem examination. All eight of these lambs had lesions in major limb joints. Three also had lesions in the atlanto-occipital joint. *E. rhusiopathiae* was cultured from the joints in seven of eight (87.5%) chronically infected lambs and detected by real-time polymerase chain reaction (PCR) in several organs. All chronically affected animals had a glomerulonephritis and six of eight (75%) had sparse degeneration in the brain. The authors concluded that these results demonstrate that chronic ovine erysipelas in sheep is not restricted to the joints, but is a multisystemic disease.

Streptococcus dysgalactiae subspecies *dysgalactiae*

There have been two recent reports on risk factors for infectious polyarthritis caused by *S. dysgalactiae* subsp. *dysgalactiae* in lambs.

The first report describes an outbreak of the disease in a commercially run research farm on the North Island of New Zealand.[14] Data from 76 affected lambs and 2223 unaffected lambs were used to evaluate risk factors for disease development. The only factors that were significantly associated with development of the disease were time of birth and birth area. Lambs born in the first six days of lambing were less likely to be affected than lambs born between days 7–18 of the start of lambing. There was no association with lamb birthweight, gender, litter size or vigour score or with dam age, body condition score or maternal behaviour score. On average, affected lambs had a 54.4 g/day reduction in growth rate from birth to weaning; at an average weaning age of 82 days this amounted to a 4.5 kg reduction in weaning weight. The pre-weaning mortality of affected lambs was 10% higher than for unaffected lambs.

The second study was a questionnaire- based cross-sectional study of Norwegian sheep farmers that classified sheep flocks of respondents as cases or controls.[15] Flock-level risk factors for outbreaks of infectious arthritis were assessed using a multivariable logistic regression model. Factors associated with a higher risk of outbreak were larger flock size, plastic mesh flooring in the lambing pen and a lambing percentage greater than 200. Flocks where farmers observed infections around the ear tags of lambs also had an increased risk of arthritis.

Acknowledgements

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Investigating animal health and diseases in Australian lamb feedlots

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Specialist lamb finishing systems (feedlots) are increasingly being utilised by Australian lamb producers to combat the seasonal fluctuations of nutrient supply in extensive pasture-based systems [1]. The practice involves removing lambs from pastures and crops and feeding groups of lambs in confined pens. Confinement feeding energy dense diets is a practical method to realise the potential of high growth genotype lambs [2, 3]. By meeting market specifications at younger ages, total nutrient intake decreases and feed resources can be prioritised elsewhere, improving overall production efficiency. Lot feeding lambs has increased in popularity due to consistently high lamb prices making the practice profitable despite considerable sources of production loss remaining unresolved [4, 5].

The practice of lot feeding lambs inherently occurs after lambs are weaned from their dams which is a known period of stress in lambs [6]. In combination with this dietary differences, potential transport and mixing of lambs of different age groups and origins as is often the case when feed lotting, exacerbates this stress and leads to immunosuppression. Under these circumstances certain infectious agents which may be present in healthy animals may cause disease in these immunocompromised lot fed lambs [6].

Nutrient intake is the primary driver of lamb growth rate and feed efficiency, consequently, any cause of reduced intake threatens to decrease production and profitability considerably [2]. Many common diseases in lamb feedlots initially result in decreased intake and frequently eventuate to removal of lambs and mortality [7]. The prevalence of certain diseases in lamb feedlots is largely unknown due primarily to a lack of diagnostics and reporting. Surveys of lamb feedlot operators have identified acidosis and shy feeding as the major contributors to production loss [4, 8, 9] however, without accurate diagnostics many producers are likely crediting unknown deaths to common causes.

This project seeks to better understand the incidence of animal health issues specific to lamb feed lotting in Australia. This will be done by using animal health and performance information from established feedlots, performing post mortem examinations on a cohort of lambs which die in these feedlots and gathering abattoir surveillance data in relation to lambs which come from the selected feedlots. This will allow identification of the most significant and prevalent animal health issues and provide insight as to how these are prevented and managed.

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Unlocking the keys to ewe survival

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Introduction

In Australia, it is estimated that annual ewe mortality is between 2-10% [1-5]. Overseas, the highest risk period for ewe mortality has been determined as the periparturient period [6] but little data in Australia are available to support this. Furthermore, the factors that cause ewe mortality are not routinely determined in sheep production systems due to labour and time constraints. Understanding the incidence of periparturient ewe mortality and reducing it should be a high priority for the Australian sheep industry both in terms of animal welfare and improving profitability. This project estimated the prevalence of non-merino ewe mortality during the periparturient period and identified the causes and risk factors associated with ewe mortality during this period in Southern Australia.

Research questions

The overall research question for this project was:
What are the causes of ewe mortality in the periparturient period for commercial non-merino ewes in southern Australia?

More specifically, the three aims of this project were to:

1. Estimate the prevalence of periparturient mortality in commercial non-merino ewe flocks in southern Australia (from the time ewes are first placed in their lambing paddocks, through to lamb marking).
2. Identify the causes of periparturient ewe mortality in commercial non-merino ewe flocks in southern Australia.
3. Identify the factors contributing to ewe mortality and the major causes of periparturient ewe mortality in commercial non-merino ewe flocks in southern Australia.

Methodology

This research project was an observational, cross-sectional study. The target population comprised of non-merino, commercial ewes in southern Australia during the periparturient period and was part of a Meat and Livestock Australia (MLA) funded research project. A total of 40 commercial farms in southern Australia which were running non-Merino breeds were chosen to be included in the study. The core data collected across all farms over two lambing periods in 2019 and 2020 was:

- Quantitative information on ewe deaths (i.e. ewe mortality across flocks).
- Post mortem examination results to determine cause of death on a sub-set of ewes (n=595).
- Management practice data associated with each flock in the project.

Results

1. <u>Cumulative mortality</u>

The mean cumulative mortality over the periparturient period (mortality expressed as a percentage of total ewes that entered the lambing paddocks, regardless of duration of observation, including all ages and litter sizes) was 1.98% in 2020 (*n*=37, 95% CI 1.86%, 2.52%) and 2.50% in 2019 (*n*=26, 95% CI 1.9%, 3.1%), ranging from 5.86% in the bottom quartile of producers and 1.28% for the top quartile of producers (Table 1).
Comparing the periparturient ewe mortality (using a paired t-test), there was no significant difference in mortality between 2019 and 2020 (P = 0.89).

Quartile	Cumulative mortality 2019	Cumulative mortality 2020
Average (0.5)	2.50%	1.98%
Top 25% (0.25)	1.44%	1.28%
Bottom 25% (1)	5.86%	5.00%

Table 1 Quartiles for cumulative ewe mortality over periparturient period

2. Farmer reported cause of death

Obvious dystocia (recorded as 'stuck lamb/s') was the most commonly recorded cause of death by farmers in both 2020 (28%) and 2019 (33%) followed by 'no obvious cause of death' (2020 24%; 2019 28%) being the next most common.

The risk of farmer reported cause of death being dystocia ('lamb stuck') was associated with age at maiden lambing. In 2019, ewes that first gave birth as ewe lambs were 2.55 times more likely to have an obvious dystocia recorded as the cause of death compared to ewes that first gave birth as two-year old maidens. This trend was noted again in 2020, with ewe lambs being 1.62 times more likely to have obvious dystocia recorded compared with two-year old maidens.

In both years, triplet bearing ewes of mixed and two or more parity had a significantly higher mean mortality compared to single bearing ewes of any parity. Single bearing, mixed parity ewes had a mean mortality of 1.73% (95% CI: 0.94, 2.52; $P < 0.05$) and 0.90% (95% CI: 0.18, 1.62; $P < 0.05$) in 2019 and 2020, respectively, while triplet bearing, mixed parity ewes had a mean mortality rate of 5.90% (95% CI: 4.92, 6.97; $P < 0.05$) and 5.06% (95% CI: 4.12, 6.01; $P < 0.05$) respectively. Twin bearing ewes of all parities had a statistically significant lower mean mortality compared to triplet bearing ewes of mixed parity.

3. Veterinary diagnosed cause of death

Veterinarian post mortem causes of death were presented as the proportion of post mortem examined ewes per farm with each diagnosis. As multiple diagnoses were possible per case, the total exceeds 100%. Septicemia, dystocia and trauma were the top 3 causes of death in both years of the study (Table 2) with septicaemia being represented by metritis and peritonitis mainly. Traumatic causes included uterine, uterine artery, abdominal musculature and bladder rupture and obturator nerve paralysis.

Table 2: Veterinarian diagnosed cause of death as a percentage in 2019 and 2020.

Cause of death	2019	2020
Dystocia (all)	41%	29%
Septicaemia	44%	42%
Trauma	19%	40%
Hypocalcaemia	10%	16%
Uterine prolapse	11%	5%
Vaginal Wall Rupture	3%	11%
Pregnancy Toxaemia	2%	1%
Cast	4%	1%
Vaginal prolapse	2%	7%
GI nematodes	3%	3%
Mixed metabolic	6%	0%
Hypomagnesaemia	2%	1%
Pneumonia	1%	8%

Mastitis	1%	5%
Other	6%	5%
Unknown	6%	7%

Of the 91 cases of primary dystocia (in 2020), 57% (95% CI: 46%, 67%) were recorded as 'obvious dystocia' with external evidence of dystocia (e.g. protruding head/s, limb/s, membranes and perineal damage), with the remaining cases identified during post mortem examination. Similarly, in 2019, 66% of cases had obvious signs of dystocia (95% CI: 56%, 75%).

Discussion

The average peri-parturient cumulative mortality rates calculated in this project mirror the annual mortality rates described in previous studies. Notably the top 25% of producers in this project had ewe mortality well below this rate which may reflect improved management practices undertaken on these properties. This assertion is currently being analysed by the project team.

Farmer reported cause of death showed similar trends to veterinary diagnosed cause of death with primary dystocia or "stuck lamb" the most common diagnosis. However, without full post mortem examination a diagnosis often could not be reached by farmers with "no obvious cause of death" being the second highest reported cause by farmers in both years.

Primary dystocia is likely to be under-reported for studies that do not include full post mortem examination. In this study, for every 2 cases of obvious dystocia, 1 extra case was missed without a full post mortem examination, highlighting the importance of veterinary involvement in sheep production systems during the peri-parturient period.

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Antibiotic use and stewardship

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Introduction

In 2019 AVA contracted the authors to write the "Antimicrobial prescribing guidelines for sheep"[1], part of the AVA series for all production species of which pigs[2], poultry[3] and sheep have now been completed. This paper briefly discusses some key findings of two surveys conducted to inform the writing of the Guidelines, the writing of the Guidelines and some areas where antimicrobial (AM) dispensing may be improved or changed because of external pressures.

Process:

Ray Batey and Paul Nilon were contracted to write the AVA's sheep AM prescribing guidelines in 2019. The writing process involved collaboration with the standing expert committee comprising Professor Glenn Browning (University of Melbourne), Professor Jacquie Norris (University of Sydney) and Dr Stephen Page (veterinary pharmacology consultant). The project was managed by Dr Amanda Black (NSW DPI). AVA policy office Dr Melanie Latter had an "overall" supervisory role.

The 2 authors had primary responsibility for different aspects of the document directly involved in antimicrobial use in sheep, while other members of the expert panel provided critical commentary as well as contributing general and supporting material to the document.

The project was in two parts: firstly, two surveys of sheep veterinarians to establish what diseases were considered important, and what antimicrobials were being used; secondly, writing the recommendations. Both parts are discussed below.

An important point of reference was the ratings the ASTAG[4] (Australian Strategic and Technical Advisory Group), which is convened by the Australian Government to provide advice on antimicrobial resistance (AMR) and antimicrobial stewardship. ASTAG rates AM's as being of low, medium or high importance to human health. Other rating systems (notably that of the WHO) were given less emphasis.

Surveys:

General survey of veterinarians treating sheep: A 4-page survey distributed via the ASV email list asked responders to list AM's they use and route of administration. This survey (unpublished) suggested that AM use in sheep was not high, and that most prescribing was of sheep-registered products in line with label directions. Importantly, only 2 drugs that had medium ASTAG ratings (trimethrorpim-sulphonamide combinations and cloxacillin) and only 1 registered product had high ASTAG rating (virginiamycin). See table 2 of the Guidelines [1].

Oral sulphadimidine is not registered in sheep but is widely used. Although generally permitted under control of use regulations there was little use of other drugs registered in other food producing animals but not sheep (e.g., toltazuril, tulathromycin, cephalosporins).

Targeted survey of veterinarians who regularly treat sheep: This phone survey targeted sheep vets in all states (except Tasmania) asking what conditions they regarded as important (see Table 1 of the Guidelines[1]) and what treatments they used. The survey results can be summarised as:

- While 19 conditions were deemed by vets to be of moderate to high importance or urgency if encountered in dairy and/or meat/wool sheep enterprises, the median frequency of veterinarians being consulted was low for the majority (15/19) of these.
- Foot abscess, virulent footrot, mycotic dermatitis, pneumonia and kerato-conjunctivitis are the diseases for which AMs are most frequently prescribed. Other infectious diseases (amenable to AM treatment) were regarded as of low importance by sheep vets, or that they were infrequently consulted by clients about those diseases.
- These two dot points support the conclusion that the prescription and use of antimicrobials is likely to be infrequent in sheep enterprises, including for high importance diseases.
- A limited range of AMs were used extensively. These included oxytetracyclines, penicillins (but not 2nd generation β-lactam drugs or cephalosporins), erythromycin, sulphonamides alone or in combination with trimethroprim and virginiamycin.
- Sheep vets frequently nominated preventive strategies (e.g., vaccination, hygiene) and alternative therapeutic strategies (e.g., footbathing, reducing stocking rate) as being more important than AMs in disease management.

While the surveys are, at best semi quantitative (i.e., qualitative), they suggest limited AM use, and that AMs were used in compliance with both labels and regulatory requirements. Importantly, most of the AMs used have a low ASTAG rating.

The following points were concluded/inferred from the surveys, and informed the Guidelines[1]:

1. A small number of infectious diseases account for most AMs prescribed by veterinarians to their clients. The range of AMs prescribed is also low, and most have a low ASTAG rating. Vets often nominate alternative strategies or therapies as most important in disease control.
2. Notwithstanding Point 1, there is an important role for AMs for specific conditions. These are often sporadic in individual flocks. There are big differences in disease frequency between seasons, location, and the type of enterprise. As sheep producers may have poor control over all the determinants of a disease condition, AMs have an important role in disease control to optimise production, maintain biosecurity and improve animal welfare.
3. Vets need to be aware of variation in States' legislation and regulations when prescribing AMs.
4. APVMA registered labels do not always reflect best practice for AM use.

Guidelines:

The guiding principles were:

1. Optimising the overall quantity of AMs used.
2. Eliminating unnecessary use.
3. Ensure prescribing practices use drugs first choice, delivered in the correct fashion and at the right dose and duration.
4. Ensure optimal biosecurity.

Other considerations included:

- Making recommendations that vets less familiar with sheep health and production could use.
- Being mindful of animal welfare (some Quality Assurance schemes may discourage AM use) and trade.
- Highlighting problematic AMs and usage.

The guidelines were written (broadly) in 2 parts: firstly, a discussion of the survey results, and then sections on the pharmacodynamics of the different drug classes, dose rates and routes of administration; secondly, short notes on the most important infectious diseases of sheep, and tabulation of disease syndromes and AM choice. The disease notes and tables were written with heavy reliance on two standard texts[5,6]. These can be examined in the Guidelines[1.]. The remainder of this paper highlights a few interesting issues of which all sheep vets should be aware.

Resistance: There is an absolute dearth of information on efficacy and resistance (apart from the first principles such as β-lactams being ineffective against *Mycoplasma* and aminoglycosides being ineffective against anaerobes). An exception is Stanger, et al, (2018)[7], where resistance of *Yersinia spp.* to sulphonamides is discussed. So, it behoves us to be more diligent in doing cultures and sensitivity and disseminating the results (even if it is through the ASV list and the newsletter).

Whole or substantial portion mob/flock treatments: The targeted survey suggested that treating a whole mob, or indeed a whole flock, was uncommon. However, several respondents reported prescribing penicillin for lamb marking. The author is also aware of an increasing trend to use AMs as repeat therapeutics/metaphylactic treatment of footrot both in Australia and NZ. These practices are not in accordance with good AMS. The disease notes and Table 3 of the Guidelines [1] highlight some scenarios where whole flock treatment may be considered. These include:

- Virulent footrot: Using AMs to reduce prevalence prior to eradication is well recognised and successful. Limiting use to infected feet during a period of no transmission is preferred. This requires the sheep be tipped for inspection. It may also be necessary to (occasionally) prevent an animal welfare disaster by treating part or whole of a mob when heavily pregnant ewes are close to lambing. Tipping heavily pregnant ewes may be difficult/ill-advised.
- *Enteric infections:* Bacterial/protozoal enteric infections present challenges. It is important we move away from "sulphadimidine deficiency" as a disease. However, withholding treatment until there is a definitive diagnosis, including C & S, may result in substantial mortality. It is also important to remember the regulatory requirements around salmonellosis, and the AMS concerns around *Salmonella spp.* as a human pathogen with capacity to develop resistance. Therefore, before starting a whole mob treatment without C & S, it is suggested the minimum background checking be:
    - Age, farm/regional history provide useful clues.
    - Eliminate parasitic and nutritional scours as a cause.
    - Perform necropsies.
    - Do C & S and change AM treatment or implement non-AM therapies accordingly. Report notifiable diseases.
- *Abortion storms:* Using AMs to stop *Campylobacter spp.* abortion storms is well referenced[5,6] but efficacy is unproven. Within the pantheon of sheep vets there are quite a few supporters. The writer is unaware of AMs being used in cases of listerial abortion, and there are no known treatments for toxoplasmal abortion (although

West, et al, list monensin as a preventive)[5]. As with enteric infections history and post-mortem examination may be used to back the decision to use AMs. Producers in high-risk environments (e.g., high rainfall, drought lots or intensive grazing, previous history of campylobacter abortion) should be counselled to vaccinate.

Virginiamycin: Recommendations around this AM generated robust negotiation. Virginiamycin is a streptogramin AM, a group that is one of the last lines of defence against vancomycin resistant *Enterococcus spp.* (VRE) and vancomycin resistant *Staph. aureus* (VRSA). It has high ASTAG importance and is under considerable scrutiny for continued use in animals. Moreover, constant use at a low dose rate in feed is tailor-made to produce resistance through direct exposure of the bacteria or via environmental contamination in the case of feedlots. The writers and standing committee took a quite hard stance with the recommendation that virginiamycin only be used in emergency situations (e.g., the need for rapid induction to grain after a fire) and limit use on farm to no more than annually. It is likely that the manufacturer (Phibro Animal Health) will be concerned with these recommendations. The current label for Eskalin 500 for cattle and poultry references the AVA dispensing guidelines[8], which, in turn reference a 2003 APVMA report[9]. We presume that the recommendations in the Guidelines[1] will supersede those of 2013, but it is unknown whether Phibro will modify the label. In the middle of 2019 Phibro had no stocks of the sheep-registered wettable powder and indicated to the author that manufacture was unlikely unless there was a considerable increase in demand. Enquiry by Dr Batey indicated that use in feed mills was declining. Therefore, users will have to use one of 2 cattle-registered formulations.

No sheep-registered product available: While it is desirable to use products that have APVMA registration for sheep, at the label dose and administration route, some diseases have no workable registered product. The outstanding example is coccidiosis, as neither toltrazuril or sulphadimidine have sheep registration. Both are registered for use in cattle. States' legislation allows use if the products are registered in other food producing species and not subject to specific exclusions or prohibitions. Prescribers are advised to examine their state's regulations, particularly regarding prescribing for mass treatment. Vets should also be able to justify the prescription with a high level of diagnostic certainty.

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Experiences with Border Disease in New South Wales

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Introduction

Border disease was first reported in the UK in 1959. It was shown to be transmissible, but it was not until 1972 that research workers at Glenfield showed that it was caused by a pestivirus infection of the pregnant ewe,[1] in a transmission trial using material from 9 to 10 week old crossbred lambs with an abnormally hairy birth coat.

Clinical signs and pathology

Clinical cases are seen when ewes become infected between 12 and 80 days of gestation. Sheep infected at other times will not show any of the clinical signs or effects of pestivirus infection.

The disease is characterised by an increased number of dry ewes in the flock, abortions, the birth of full term lambs with abnormally hairy birth coats and poor viability in the lambs that survive the first few weeks of life. In some flocks, the hairy shaker condition is seen, characterised by hairy birth coats, tremors and incoordination and swaying of the head and neck.

The increased number of dry ewes is the result of foetal mummifications and unobserved abortions in the early stages of pregnancy. Even in pen situations, these were often hard to detect. Aborted lambs that could be examined and other affected lambs will have hypomyelinogenesis and may also have focal leukomalacia and cerebellar hypoplasia. Other lesions seen in lambs born to ewes exposed at the susceptible stages of pregnancy included arthrogryposis, micrencephaly, porencephaly and brachygnathia.[2,3]

The clinical signs will vary according to the source of the inoculum[3]. In the early trials at Glenfield, the nervous forms of the disease were not seen, but lambs born to ewes infected in the susceptible stages of pregnancy has hairy birth coats and hypomyelinogenesis. Lambs born to ewes inoculated with material from hairy shaker cases all showed the nervous form of the disease. This indicates that there may be several strains of the virus in the field.

The other feature of the disease is that clinically affected lambs that survive past birth are immunoincompetent and will not develop antibody. If sampled after they have suckled, then they will have colostral antibody that will persist for 8 to 10 weeks. Once this is lost, then they become susceptible to a range of conditions. They will exhibit illthrift and usually die with signs of scouring and pneumonia. A small percentage of these lambs may survive for at least 2 to 3 years.

Diagnosis

Serology uses the AGID test. This was also used to detect virus in material from foetuses and lambs. However Elizabeth Macarthur Agricultural Institute (EMAI) is now using a Pesti qRT-PCR on this material to detect virus.

From a flock point of view, serology on a sample of ewes in the flock will demonstrate previous exposure to infection. However if the sheep were not exposed at a susceptible stage of pregnancy, then clinical disease would not be seen. The chronically infected carrier ewe will be antibody negative, but will be excreting virus. If she survives to breeding age, then she will give birth to an infected lamb that will be antibody negative.

Diagnosis in the foetus and affected lamb is based on virus isolation. This will be difficult from autolysed or mummified foetuses or from lambs that have suckled and may have colostral antibody. In these older lambs, then diagnosis is best based on clinical signs. In weaners and older sheep, then selective sampling of sheep with abnormally hairy fleeces for virus isolation is suggested.

One of the problems with the newer breeds that shed their fleeces or that have hairy fleeces is that the affected animals are much harder to detect. The same problem arises with first cross ewes, making it difficult to detect the carrier animals on clinical grounds. The use of serology to detect these animals in a flock is not recommended because of the cost involved. If there is a need to test the flock, detect the antibody negative animals and then sample these to detect the viraemic animals.

Transmission of infection

Transmission of infection occurs from the persistently infected animal when it becomes colostral antibody negative. In our trials, where exposed and non-exposed ewes were maintained in small groups on deep litter, we found no evidence of transmission of infection at parturition. This was despite the fact that pestivirus could be isolated from blood and tissues of affected lambs.

In a paddock transmission trial at Glenfield (unpublished), we were able to show that the disease was readily transmitted from the persistently infected carrier animal. We put 2 carrier animals into a group of sheep for 2 week periods with a 2 week interval in between. Transmission, as evidenced by serology, only occurred when the carrier animals were present in the mob, indicating that the sheep incubating the disease were not transmitters.

Epidemiology

The transmission of the disease within a flock requires the presence of persistently infected carrier animals in the flock. When investigating an outbreak of border disease within a flock, one has to go back to what happened to the flock when the affected ewes would have been at a susceptible stage of pregnancy i.e. from 12 to 80 days of gestation. There will normally be some change in flock management that has led to the exposure of susceptible ewes to the carrier animal.

There are two situations where this can occur in a flock. These are:

1. When a carrier animal is introduced into a naïve mob. This usually occurs with replacement breeding stock. It may not be so obvious in the introduced animals in that they would have been running with the carrier for some time and would have been exposed to infection prior to mating. However the mixing of mobs from various sources prior to joining will increase the risk of outbreaks if there are carrier animals in one of the mobs. Some the newer breeds have hairy fleeces and affected lambs will be difficult to identify at lamb marking, let alone when they are older.
2. When ewes are being joined in mobs where there are older lambs at foot from an earlier joining. This is believed to be a problem with ewes in the pastoral areas where fences may not be good and rams join at other than the normal joining periods. Border disease has been described in flocks at Broken Hill[4] and in sheep at Cobar.[5] Whilst sheep are run at very low stocking rates on these properties, sheep do aggregate in shaded areas and on dam banks.

Ewes from these flocks are often sold into the wheat-sheep areas of the state to be joined to other breeds to produce prime lamb mothers. There is a risk of carrier animals surviving in some of the replacement ewes and they will be difficult to recognise on the basis of fleece characteristics.

The recent changes with the breed structure and joining management on properties running the newer breeds are likely to cause problems in controlling the disease. With some breeds, ram control is not easy and extended joining periods are often the result. Other flocks are joining ewes at a much younger age, with less chance of them having been exposed to infection before joining.

Control of infection

Control of infection in a flock is achieved by ensuring that ewes are not exposed to carrier animals at susceptible stages of pregnancy:

1. Identifying infected lambs at birth or at lamb marking and ensuring they are removed from the flock before any joining takes place. Affected lambs will have an abnormally hairy birth coat and will have lower body weights than lambs of similar age in the flock. Identification of these lambs may be difficult in some of the hairy breeds and those that shed their fleeces.
2. In merino flocks where the mothers of affected lambs can be identified, then a careful examination may reveal evidence of abnormal fleece characteristics that may suggest a carrier. Blood testing of these sheep and other sheep that are either dry or have lost their lambs would be expensive. Ewes with positive blood tests are likely to be immune.
3. Avoid joining ewes in flocks where some ewes still have lambs at foot.
4. Where possible, keep introduced ewes separate from other sheep on the property until after joining.

Nothing is known about the prevalence of Border Disease in goats in western NSW, even though we know goats can be infected.

In flocks where the disease was diagnosed some years ago, better joining management to avoid joining ewes in mobs where there are lambs at foot eliminated further outbreaks. The disease is usually self-limiting in closed flocks because the carrier animals will soon infect most ewes in the mob.

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Goats: Where are we now? Where are the low-hanging fruit?

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Introduction

The meat goat sector may become a major red meat commodity in NSW and QLD. The animal is hardy and robust and well suited to rangelands and semi-arid conditions. In 2019, the average carcase price for goat meat was $7.60/kg CWT [1], a substantial increase on the 5-year average of $5.41.

A report into the priority diseases endemic to the red meat industries was published for Meat and Livestock Australia (MLA) in 2015.[2] The method to identify the diseases and the cost to industry was undertaken via surveys of veterinarians and producers of the cattle, sheep and goat sectors, supported by literature reviews. Estimates for the cost of dystocia was $97.8M and neonatal calf mortality was $96.1M and for the sheep industry, the same diseases were estimated at $219.16M and $540.4M respectively. For the goat industry these diseases were not identified as a priority disease. It isn't clear if the survey method simply missed these issues or if they weren't important, but the findings did not resonate with influential meat goat breeders.

MLA subsequently called for tenders to examine the issue of kid loss in the managed meat goat sector and a collaboration between NSW Department of Primary Industries (NSW DPI) and Charles Sturt University (CSU) was successful.[3] The project had numerous lines of investigation and herewith, this discussion will focus on the on-farm pregnancy scanning and kid marking results, their context in view of the global literature reports for goat reproduction and the effect these had on our estimates for the cost of reproductive wastage in the managed meat goat sector.

From the first pregnancy scanning events it was immediately clear that doe age was a major factor affecting pregnancy rates, hence the review of literature [3] and industry level estimates for the cost of reproduction were broadened to include pregnancy rate and kid loss. Pregnancy rates varied among the 9,187 does scanned, averaging 71.5% and ranging from 45% to 97%. Kid survival also varied, with 7,028 kids marked from 10,812 fetuses identified at pregnancy scanning, averaging 65% and ranging from 27% to 93%. Together the average kid marking rate per doe scanned was 76.5% and ranged from 37% to 130%.

Kid survival from maiden does was very poor, averaging 36%. In these herds, maidens were about 25% of all breeders and marked 13.5% of all kids.

The economic analysis for reproductive wastage estimated that similar magnitude gains could be made in the industry by improving fertility rates as well as reducing kid loss. For instance, assuming an average fertility of 71%, and a kid loss rate of 20%, increasing average fertility to 79% in NSW would increase annual industry value by $777,127 in NSW and $529, 970 in other jurisdictions. If kid loss is 20% at a fertility of 71%, the estimated income foregone per annum is NSW is $862,165, and $587,880 in the other jurisdictions.

The following discussion details how these findings were created and conclusions and recommendations are drawn for the managed goat meat sector.

On-farm pregnancy scanning

Meat goat producers in the *managed* sector of the NSW and QLD regions industry were the primary target for engagement for the project B.GOA.1905.[3] In total, 10 producers were sufficiently confident to retain the scanned does through to marking, given the intense drought conditions in NSW and QLD in 2019. These producers were based in NSW (n=8) and QLD (n=2). Real-time ultrasound pregnancy scanning occurred within 100 days of the bucks being introduced, and typically around 86 days. A total of 33 mobs were scanned, with 9,187 does examined. The production zones included Rangeland, Northern high rainfall and Southern high rainfall. Does were joined and kidded across the seasons, including autumn, winter, spring and summer. The spread of seasons provides helpful data for industry.

The average herd fertility was low in 2019 and the widespread and long-term, intense drought had a depressing effect on body condition at joining, leading to lower fertility and conception rates and possibly lower ovulation rates, although the number of fetuses per pregnant doe was high and reflects well against the literature.[4] The weighted mean fertility was 71.5% (Table 1) and the weighted mean kid survival was 65.0%, resulting in a mean marking rate (kids marked per doe scanned) of 76.5% (Table 2). The producers were asked to manage the does according to their normal management practice for the circumstances facing the operation. On some farms it was possible to identify maiden does from adult does. The maiden class includes doe-kids, which are similar to ewe lambs in the sheep industry that are mated to lamb at about 12-14 months of age. Their exposure to the bucks did contribute to the lowest pregnancy rates observed, but do not explain all low fertility rates observed (Table 3). The mean pregnancy rate for the maidens was 47.7% and the mean litter size was typical for all pregnant does around 1.61. Mean doe and kid survival rates were poor, respectively 87.2% and 37.8%.

Table 4 reports for herds where adult and maiden does were kidded separately and shows the kid survival rate for adult does was 60.5% and for maidens was 35.8%, resulting in 88.8% and 45.9% kids marked per doe scanned, respectively. In these herds, maidens occupied 22% of the does numbers and weaned 13.5% of all kids. However, maiden fertility was much improved (75.5%) when compared herds where maidens were not separated. The conception rate of all adult does was 81%, but in operations where adult does were separated, the conception rate was higher at 86%. Taken together these differences imply that differential management according to age has reproduction benefits, presumably due to the ability of managers to allocate feed resources appropriately.

Among the participating properties, Farm A (Table 1) was an agreeable manager of a goat depot in far western NSW. At this location, rangeland, wild harvest does were pregnancy scanned and those with an identifiable litter size were retained for kidding. The drought conditions were severe throughout gestation and lactation. Farm J was located in central QLD and is new to goat production and operating a semi-managed operation, also experienced difficult and severe drought conditions. All other operations were managed enterprises. Some maiden does on Farm F experienced spontaneous nutritional abortions. The does on Farm G experienced challenging nutritional shortages as the drought was very difficult in their location, leading to abnormally high kid losses.

From these highlighted examples, the results of the 2019 on-farm survey can be contextualised to some degree. The circumstances these producers were bound to manage were very difficult. How well the 2019 reproduction rates reflect long-term performance is difficult to ascertain. The most valuable observation this study has made is the potential for high marking rates coupled with high doe survival.

Table 1. Pregnancy scanning results for meat goat herds, including the number of does scanned, the number of non-pregnant (Dry) does, the number of pregnant does bearing a single, twin or triplet litter and the reproduction rates (%) for fertility, the scanning rate (number of fetuses/number of does scanned). Among pregnant does, the proportion of which are bearing one (Single %) or more than one foetus (Multiples %) and the total number of fetuses per pregnant doe (Fetuses per wet doe %).

Producer	Scan date	Does scanned (*n*)	Dry (*n*)	Single (*n*)	Twin (*n*)	Triplet (*n*)	Fertility (%)	Scanning (%)	Single (%)	Multiples (%)	Fetuses per wet doe (%)
A (NSW)	5/04/2019	605	212	252	141		65 %	88 %	64 %	36 %	136 %
B (NSW).1	24/04/2019	1178	178	364	636		85 %	139 %	36 %	64 %	164 %
C (NSW)	24/05/2019	1040	432	235	369	4	58 %	95 %	39 %	61 %	162 %
D (NSW)	13/06/2019	183	9	25	130	19	95 %	187 %	14 %	86 %	197 %
E (NSW)	19/06/2019	924	375	329	218	2	59 %	83 %	60 %	40 %	140 %
F (NSW).1	25/06/2019	387	51	153	178	5	87 %	135 %	46 %	54 %	156 %
G (NSW)	28/06/2019	95	4	41	50		96 %	148 %	45 %	55 %	155 %
F (NSW).2	2/07/2019	283	46	82	151	4	84 %	140 %	35 %	65 %	167 %
H (NSW)	18/07/2019	2038	782	418	786	52	62 %	105 %	33 %	67 %	171 %
I (QLD)	25/08/2019	284	22	58	204		92 %	164 %	22 %	78 %	178 %
J (QLD)	24/09/2019	845	464	145	236		45 %	73 %	38 %	62 %	162 %
B (NSW).2	15/10/2019	1325	43	310	972		97 %	170 %	24 %	76 %	176 %
Total		9187	2618	2412	4071	86					
Mean		765	218	201	339	14	71.5 %	118 %	26.3 %	46.1 %	165 %

Note: Where indicated under Producer, the .1 or .2 denotes the first or second herd scanned, with separate mating periods and different date of scanning.

Table 2. Kid marking results from pregnant does, including the number of does not rearing kids (KL) kids marked per doe scanned (KM/DS) and the number of kids marked per doe at marking (KM/DM).

Producer	No. pregnant does (*n*)	Scanned fetuses (*n*)	Does at marking (*n*)	Kids marked (*n*)	Rearing does[1] (*n*)	KL & dry does[1] (*n*)	Doe survival (%)	Kid survival (%)	KM/DS (%)	KM/DM (%)	% Dry does
A (NSW)	393	534	316	257			80.4 %	48%	42 %	81 %	
B (NSW)-1	1000	1636	998	1469			99.8 %	90%	125 %	147 %	
C (NSW)	608	985	601	913	547	54	98.8 %	93%	88 %	152 %	9%
D (NSW)	174	342	174	191	160	26	100 %	56%	104 %	110 %	14%
E (NSW)	549	771	535	514	444	91	97 %	67%	56 %	96 %	17%
F (NSW)-1	336	524	328	217	205	123	98 %	41%	56 %	66 %	38%
G (NSW)	91	141	91	41	43	48	100 %	29%	43 %	45 %	53%
F (NSW)-2	237	396	228	106	101	127	96 %	27%	37 %	46 %	56%
H (NSW)	1256	2146	1167	1111			93 %	52%	55 %	95 %	
I (QLD)	262	466	284	370	265	21	108 %[2]	79% [2]	130 %[2]	130 %	
J (QLD)	381	617	347	540			91 %	88%	64 %	156 %	
B (NSW)-2	1282	2254	1201	1299			94 %	57.6%	98 %	108 %	
Total	6569	10812	6270	7028	1765	490					22%
Mean	901	547	523	586			95.4 %	65.0 %	76.5 %		

Note: Where indicated under Producer, -1 or -2 denotes the first or second herd scanned, with separate mating periods and different date of scanning.

[1] Counts of does not rearing kids was based on udder inspection and provided for where research staff were in attendance. When non-pregnant does were retained with the kidding does, adjustments to the tally of dry does was made.

[2] At this property, more does were counted than were scanned and that data is not included in the reported mean for all farms.

Table 3. Maiden reproduction performance with, where available, results when kidded separately from adults, the number of does not rearing kids (KL) and the number of kids marked per doe scanned (KM/DS).

Producer	No. does scanned (*n*)	Fertility (%)	Scanned fetuses (*n*)	Fetuses per wet doe (%)	Does marked (*n*)	Kids marked (*n*)	Rearing does (*n*)	KL & dry does (*n*)	Doe survival (%)	Kid survival (%)	KM/DS (%)
C (NSW)	516	19.4 %	128	128 %							
D (NSW)	91	95.6 %	168	193 %	87	91			100 %	54 %	100 %
E (NSW)	364	18.4 %	71	20 %							
F (NSW)	283	83.7 %	396	167 %	228	106	101	127	96 %	27 %	37 %
G (NSW)	34	100 %	50	147 %	34	11	9	25	100 %	22 %	32 %
H (NSW).S	440	64.1 %	472	167 %	209	181			74 %	38 %	
H (NSW).B	184	66.3%	217	178 %							
I (NSW).a	48	47.9 %	30	130 %							
I (NSW).b	52	17.3 %	14	156 %							
Total	2012		1546		558	389	110	152			
Mean		47.7 %							87.2 %	35.8 %	45.9 %

[S] denotes does were kidded separately to adults

[B] denotes does were kidded with adults

.[a] denotes maiden does mated and not rearing kids at the time of pregnancy scanning

.[b] indicates maiden does that were rearing kids at the time of pregnancy scanning.

Table 4. Comparison of adult doe reproduction performance against maiden reproduction performance, where does were kidded separately.

Class	No. does scanned (*n*)	No. pregnant does (*n*)	Scanned fetuses (*n*)	Kids marked (*n*)	Fertility (%)	Kid survival (%)	KM/DS (%)
Adult	2952	2544	4331	2621	86.2%	60.5%	88.8%
Maiden	848	640	1086	389	75.5%	35.8%	45.9%
Total	3800	3184	5417	3010			

A general observation was made for all herds that udder and teat shape varied considerably and too many does had dysfunctional teats and udders. This observation requires more specific data record keeping but efforts directed toward culling does with poor teat and udder structures would lead to long-term improvements in the herd.

The conclusions from this work demonstrate clearly that maiden doe management can be substantially improved. These results imply that separate management of does according to their age will have benefits for the industry and warrants further research. The attitude of exposing young does to bucks, “because a few extra weaners is a bonus” is a mindset the industry must challenge. The pregnant doe that successfully conceives but fails to rear kids are occupying precious feed resources (grain and grass), especially in difficult drought conditions. Further research, development and adoption is warranted to explore the management requirements to lift the rearing success of maidens, as well as lifting the fertility and kid survival for all does.

Estimating the cost of reproductive wastage

This economic approach estimates the value foregone via reproductive wastage through fertility rates and kid loss rates. Assumptions had to be made for the size of the managed meat goat population.

The 2016 Agricultural Census found that there were 424,913 managed goats in Australia in the “Livestock - All other livestock - Goats (excluding unmanaged feral goats)” category.[5] These numbers do not include the number of rangeland goats Australia, which were estimated to be between 4-6 million in 2017.[6] In order to estimate the number of breeding does in managed meat goat herds, the 2015-2016 Agricultural Census numbers were adjusted for an estimated proportion of bucks (2%) and young stock (53%), and the number of does used for milk production was subtracted (n=30,551 dairy does).[7] The mohair industry goat numbers were estimated to be 8,334 (Steve Roots, *Executive Officer, Australian Mohair Association, Nov 2019,* pers.comms) and subtracted. NSW DPI gross margin budgets for Dorper (meat) sheep indicate 21.7% of females are kept for breeding so in the absence of goat industry data, this was used as the base figure for number of females kept for breeding.[8] Table 5 shows the calculations resulted in an estimated 158,761 managed meat does in Australia.

Table 5. Estimated number of managed meat goat does by jurisdiction.

Jurisdiction	Managed Goats 2016 Ag Census	Estimated total does	Estimated milking and angora does	Estimated total meat does
NSW	231,061	106,011	6,862	99,149
Queensland	109,516	50,246	5,719	44,527
Victoria	35,735	16,395	14,296	2,099
South Australia	22,976	10,541	3,431	7,110
WA, Tas & NT	25,626	11,757	8,577	5,876
TOTALS	424,914	194,950	38,885	158,761

Data provided by the Australian Bureau of Statistics (ABS) [5] and MLA [9] for number of goats slaughtered, tonnes of goat meat by carcase weight (cwt) and prices in c/kg cwt were used to derive the average carcase weight and price per kg (Table).[5, 9] The five year average price is 541 c/kg cwt and this price was used in the valuation of sale stock in the calculations.[9]

Table 6. Average carcase weight (kg) by state, 2014-2019.

	Australia	Queensland	NSW	Victoria	SA	WA	Tasmania
Average cwt/hd	14.9	16.8	14.2	14.4	13.7	14.7	13.5

Fertility rates obtained from the project field work indicated an average fertility rate of 71% and a kids per wet doe figure of 160%.

Results

Table reports the value of production in NSW and the value of kid loss on an annual basis and the difference. At a rate of 20% kid loss, an extra 11,264 kids would not have survived between birth to saleable age. The estimated number of saleable progeny is then multiplied by the long-term average price and average carcase weights. Figure 1 shows the difference for NSW and the other meat goat jurisdictions across a range of kid loss rates. AS the kid loss rate increases, the value to the industry foregone also increases.

Table 7. Value of kid loss (NSW 2015-16).

	Number kids sold for slaughter	kg/head cwt	Price per kg cwt	Value of production
71% fertility, 10% kid loss	77,873	14.2	$ 5.41	$ 5,960,526
71% fertility, 20% kid loss	66,609	14.2	$ 5.41	$ 5,098,361
Difference foregone due to10% higher kid loss				$ 862,165

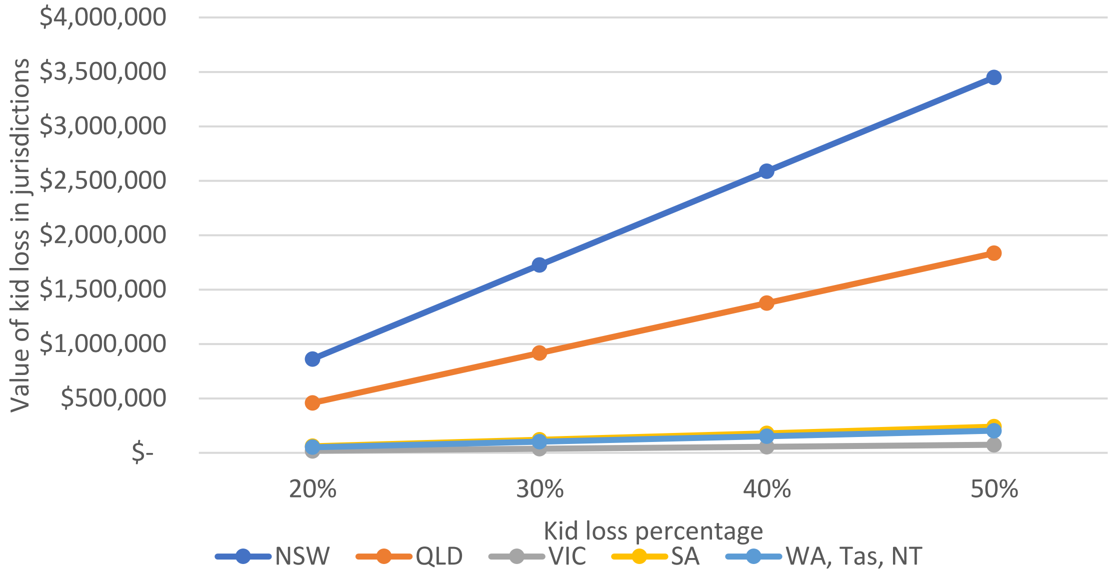

Figure 1. Estimated value of kid loss by jurisdiction (compared to best case of 10%, with fertility rate 71%)

Sensitivity testing

Figure 2 shows the estimated annual value of kid loss at different kid loss rates and the full range of measured fertility rates to date for NSW. For example, if the current rate of kid loss is 30%, at the currently estimated rate of 71% fertility, the value of losses (i.e. income foregone) to the NSW industry is $1.72m per annum. If kid loss is 20%, the estimated income foregone per annum is NSW is $862,165.

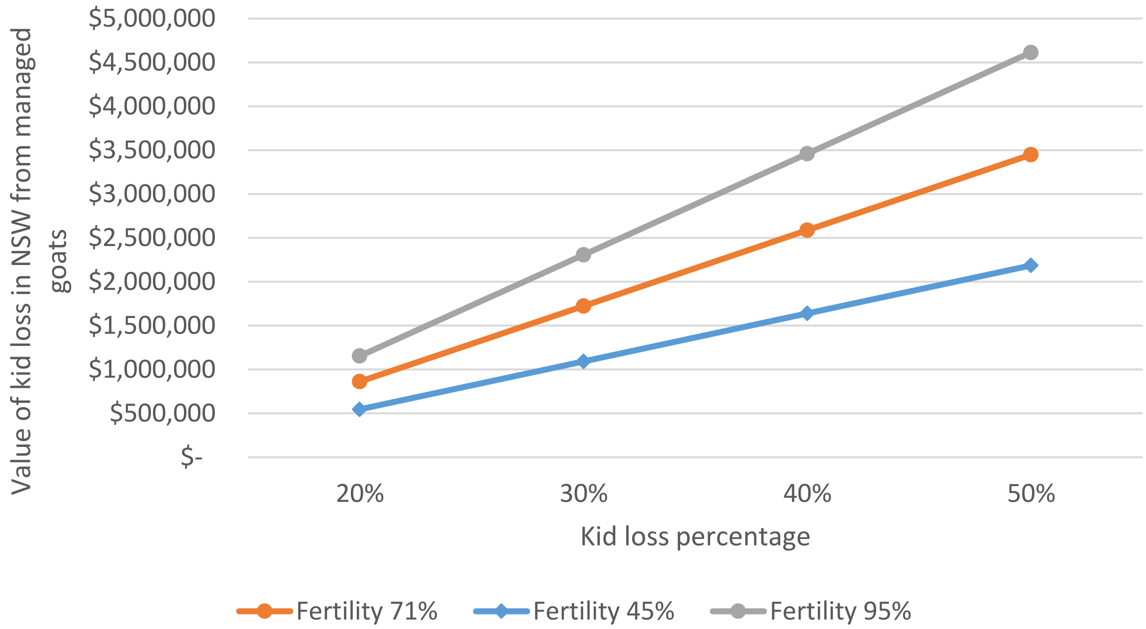

Figure 2. Estimated value of kid loss in NSW (compared to base case of 10% kid loss).

Figure 3 reports the range of foregone industry value for different fertility rates, at 20% kid loss. For example, if fertility is 71%, improving average fertility in NSW to 79%, would gain the industry an extra $77,127 per annum.

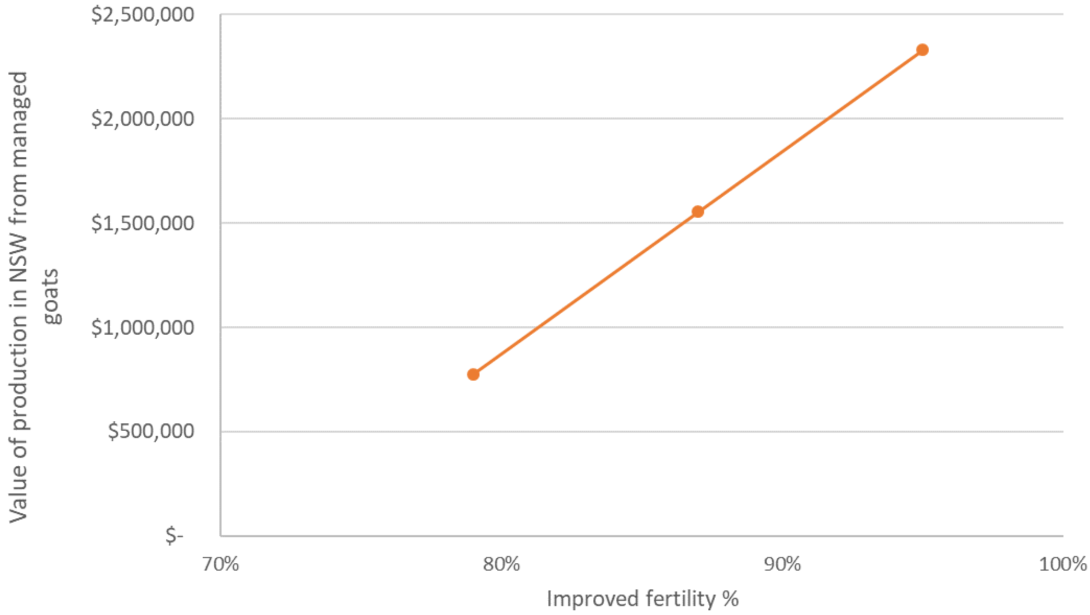

Figure 3. Estimated values of fertility changes for NSW (n = 99,149 does).

This methodology indicates there are economic gains of a similar magnitude to be made in the industry by improving fertility rates as well as reducing kid loss, at the carcase weight and carcase price considered. The assumption for carcase weight were taken from commodity values and are not available for classes of management system. Managed meat goats are most likely to produce heavier carcases which are explored in Table 8, which also explores price variation. Across the full range of variable presented, the value of 10% higher kid loss is equivalent to between $8.73 lost for all managed does and as high as $15.32.

Table 8. Industry value foregone when fertility is 71% and kid mortality is 20% when compared to 10%. A range of price ($/ kg carcase weight (cwt)) and carcase weight (CWT, kg) scenarios are presented for the NSW managed meat goat sector (n = 99,149 does).

	Price ($/kg cwt)		
cwt (kg)	$5.41	6.41	$7.41
14.2	$865,323	$1,025,272	$1,185,221
15.2	$926,261	$1,097,474	$1,268,687
16.2	$987,199	$1,169,676	$1,352,153
17.2	$1,048,138	$1,241,879	$1,435,619
18.2	$1,109,076	$1,314,081	$1,519,086

Conclusions

The field study examining kid loss rates in 10 commercial managed meat goat herds revealed a large range of kid marking rates, impacted by low fertility and kid survival. Maiden does performed poorly as a class of breeder.

The field study results informed the estimates made for the cost of reproductive wastage in the sector. Assumptions had to be made for population size, which provide the sector with useful estimates. The industry value foregone due to reproductive wastage is similar between fertility and kid loss, being slightly higher with kid loss rates at the carcase weight and price assumptions provided. When kid loss increases by 10%, about $8.73 is lost for every doe mated. Translating that loss across all Australian meat does becomes a substantial sum.

Acknowledgements

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The right advice on resistance – dicyclanil and monepantel

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Introduction

The ongoing availability of effective parasiticides is essential for Australian sheep producers. Insecticide resistance has the capacity to seriously impact animal welfare and the profitability of our animal production systems.[1] Unfortunately, the number of novel molecules is limited and it is important that we preserve the efficacy of our current products for as long as possible.

Sustainable parasite control relies on integrated parasite management principles, including adoption of non-chemical controls to reduce reliance on chemicals where possible. Equally, it has long been clear that we need to use chemicals in a way that minimizes the risk of selection pressure leading to resistance.[1,2]

Dicyclanil is widely used for the protection of sheep against flystrike by the Australian sheep blowfly (*Lucilia cuprina*) and is a critical molecule for sheep management and welfare.

The development of resistance to dicyclanil is an emerging challenge for producers and advisors. We now have good baseline information on the prevalence and severity of resistance. We also have a range of industry recommendations to be able to minimize selection pressure for resistance – and resources to support this advice.

Monepantel is the only member of the amino-acetonitrile derivative (AAD) or 'orange' class of anthelmintics. With widespread resistance to the older drench classes, monepantel is a critical molecule in the sustainable control of internal parasites.

A case of resistance to monepantel in *Teladorsagia (Ostertagia)* has been confirmed for the first time on a large-scale commercial sheep property in Western Australia (WA). The key findings from this case reinforce known risk factors for the development of resistance and steps that can be taken to reduce selection pressure on this molecule.

Dicyclanil resistance

Dicyclanil has been widely used for the prevention of flystrike since 1998. Resistance was first detected a decade ago, in the 2010/2011 fly season.[3]

At that time, laboratory bioassays demonstrated low-level resistance, with the index fly strain 2.1-fold more resistant to dicyclanil than a reference susceptible strain at the LC95 level.[3] In a follow-up larval implant study, the period of protection against this fly strain was shown to be unaffected[2] – despite the increased tolerance to the chemical. A field study on the property of origin also demonstrated full protection[2] – again, despite the fly population demonstrating 'known' low-level resistance.

Incidentally, the initial strain was only detected due to a breakdown in protection with cyromazine – in association with minor underdosing.[3,4] Cyromazine resistance was subsequently confirmed along with low-level cross-resistance to dicyclanil.[3]

An Australian Wool Innovation (AWI) survey (2012-2014) demonstrated that similar fly populations existed elsewhere. Of 58 fly strains submitted from around the country (NSW 28; WA 17; Vic 6; SA 2; Tas 5), 36 demonstrated low level resistance to cyromazine. Of these 36, 8 strains also demonstrated low-level 'cross-resistance' to dicyclanil.[5]

The chemical structure of cyromazine and dicyclanil are known to be similar[5], but dicyclanil has been shown to be approximately 10 times more potent than cyromazine against *Lucilia cuprina*.[5,6]

It is important to note that cyromazine resistance appears to occur without dicyclanil resistance, but dicyclanil resistance does not occur without cyomazine resistance. It appears that cyromazine resistance is required for dicyclanil resistance to occur i.e. the development of dicyclanil resistance requires the presence of genetic variation provided by cyromazine resistance.[7]

A more recent AWI survey (2018-2020), in partnership with NSW Department of Primary Industries (DPI), demonstrated an increase in the prevalence of resistance to cyromazine and to dicyclanil. Of 100 fly strains submitted from around the country (NSW 55; WA 21; Vic 11; SA 12; Tas 1), 88 demonstrated a level of resistance to cyromazine. Of these 88, 73 also demonstrated resistance to dicyclanil. As previously, cyromazine resistance was observed independent of dicyclanil resistance. However, dicyclanil resistance was always associated with cyromazine resistance.[7]

It has been noted that these were not a random selection of strains – and therefore the results should not be interpreted as an estimate of the true prevalence of resistance.[8]

The severity of resistance has also increased. Where the previous survey demonstrated surviving larvae at the "susceptible discriminating concentration" (SDC) of 0.1ppm dicyclanil (mg/kg), the latest survey demonstrated surviving larvae at 4-fold and 8-fold the SDC. The frequency of dicyclanil resistant flies within these strains ranged from 2% to 93% – noting however, as above, that these were not a random selection of strains.[8]

Impact on protection

To assess the effect of resistance on protection from flystrike, sheep were exposed to resistant larvae using an 'implant' technique.

Prior to the study, the resistant larvae were pooled into pure-breeding strains through ongoing exposure to the higher screening levels of dicyclanil (4-fold and 8-fold the SDC), eliminating susceptible types.[5] These composite strains were selected in this way for 3 generations before resistance ratios were measured. The fly strains were 23.6 and 36-fold more resistant to dicyclanil than the reference susceptible strain at the LC95 level, respectively – prior to commencement of the larval implant study.[5] Selection continued in this way throughout the implant challenge for a total of 10 generations, ultimately becoming 40.4 and 39.8 times more resistant to dicyclanil than the reference susceptible strain at the LC95 level – measured at the completion of the study.[5]

Accordingly, the flies used in the larval implant study comprised the most resistant strains found in the survey[8] – exposed to further selection pressure and with susceptible types eliminated. It has been noted that on most properties, even where some resistance exists, the level of resistance is likely to be lower than in the flies used here.[8] At this point in time, there are certainly no known field strains with resistance as high as documented here.

The method is also a more severe challenge than likely in most field situations – and therefore provides something of a "worst-case" scenario[8] – and what 'could' eventually happen at field level.

The results showed the extent to which protection from flystrike may be compromised in the face of severe fly challenge with highly dicyclanil-resistant flies (Table 1).

Table 1

Length of protection against flystrike (larval implant) observed against a composite dicyclanil-resistant fly strain maintained by laboratory selection with dicyclanil.[5,8]

Chemical	Dicyclanil	Dicyclanil	Dicyclanil	Cyromazine	Ivermectin
Concentration of active	12.5g/L	50g/L	65g/L	500g/L	16.0g/L
Application method	Spray-on	Spray-on	Spray-on	Jetting	Jetting
Length of protection	<3 weeks	<4 weeks	<9 weeks	<7 weeks	<8 weeks

While we now know that field resistance may result in a reduced protection period of sheep from flystrike, we also know that control failure is commonly due to inadequate chemical application such as underdosing or poor application technique.[1] Producers may therefore inadvertently confuse control failure with insecticide resistance, while simultaneously contributing to circumstances that may increase selection pressure for the development of resistance.[1]

In many cases, investigations into product breakdown reveal a range of contributing factors, including sub-standard product application but also leaching of chemical from wool by excessive rainfall or unrealistic expectations of product effectiveness.[3] It is important that advisors consider the full range of factors that may contribute to a reduced period of protection to ensure the producer is best able to achieve the optimum level of protection when using the product again in future.

Resources

AWI has consulted widely on sheep blowfly resistance and has produced a range of resources that will assist advisors and producers:

https://www.wool.com/globalassets/wool/sheep/welfare/breech-flystrike/its-fly-time/accordion-4/gd3349-awi-sheep-blowfly-resistance-management-strategy.pdf

https://www.wool.com/globalassets/wool/sheep/research-publications/welfare/non-invasive-management-practices/insecticide-resistance-study-btb-dec-2020.pdf

https://www.wool.com/globalassets/wool/sheep/welfare/breech-flystrike/its-fly-time/accordion-5/gd4044-awi-a-fly-in-the-ointment---limit-further-development-insecticide-resistance.pdf

Monepantel resistance

After an extensive research and development program, monepantel was first brought to market in Australia in 2010 – as a novel active providing high level broad spectrum efficacy against gastrointestinal nematodes in sheep.[9] Its introduction was timely considering the prevalence and severity of resistance to the older anthelmintic classes.

Resistance to monepantel was first reported in goats in 2014,[10] despite not being registered for use in that species. Isolated cases of resistance in sheep were then reported from within research institutions (Veterinary Health Research Pty Ltd, Armidale and Charles Sturt University, Townsville)[11,12] in *Haemonchus* and *Trichostrongylus*.

Field resistance on commercial sheep farms was first detected by Elanco in 2015,[13] in *Haemonchus.*

Subsequent reports of field resistance have followed. Sales and Love reported resistance in *Haemonchus* in 2016,[14] and Lamb *et al.* also reported resistance in *Haemonchus* in 2017.[15]

The first known case of resistance to monepantel in *Teladorsagia (Ostertagia)* has now been confirmed on a commercial sheep property in Western Australia – and is reported here.

Elanco was contacted in November 2018 regarding worm egg count (WEC) results which indicated reduced effectiveness of monepantel on a large property in the Great Southern region of Western Australia, north west of Albany. A full drench resistance test was conducted on-farm in December 2018, with full results reported in early 2019 (Table 2).

Table 2

Drench resistance test results (on-farm FECRT).

	Teladorsagia	*Trichostrongylus*	*Haemonchus*
Monepantel	62%	100%	100%
Abamectin	100%	100%	100%
Monepantel + Abamectin	96%	100%	100%

Larvae were also submitted to the Elanco research property in NSW (Yarrandoo), where a Total Worm Count study was conducted. Results confirmed resistance in this strain (Table 3).

Table 3

Drench resistance test results (Total Worm Count Study).

	Teladorsagia			
	Amean	Efficacy	Gmean	Efficacy
Control	516.7		505.7	
Monepantel	83.3	83.9	80.1	84.2
Abamectin	100	80.6	95.9	81.0
Monepantel +Abamectin	30.0	94.2	21.5	95.7

The property is located in an area with a relatively mild Mediterranean climate. Annual rainfall is approximately 900 mm with very dry summers.

The worm control program followed on this property is high level, adhering closely to best practice guidelines for this region. Anthelmintic resistance management strategies are in place, involving a minimum frequency of drenching, appropriately-timed strategic treatments, monitoring of worm egg counts at intervals, and a number of non-chemical sheep and pasture management strategies.

However, at least in some cases monepantel appears to have been used in a situation of close to zero refugia for worms with no previous exposure to monepantel. After weaning in December, lambs are drenched and moved onto prepared fodder crops on specifically-managed paddocks, consisting of oats, lupins, rye-grass and clovers. These pastures are dry by the time the lambs arrive, and as they are sown in early winter, represent a completely worm-free situation. The weaners remain set-stocked for some months, for at least the summer period.

As no re-infection with infective larvae is possible, any worms surviving treatment become the source of future worm populations. This exerts high selection pressure in the same way that occurs when sheep are drenched onto crop stubbles – risk factors that are well understood through experimental work in WA.

In this case it was recommended to reduce the selection applied by the treatment of lambs in summer. A small less-resistant population could be allowed to survive by either delaying the summer drench for a short period (1- 2 weeks) after a move to forage crops, with subsequent worm egg count monitoring to check that worm burdens remain low.

Due to the large scale of this property, there was also the possibility that the test results may represent a distinct 'sub-population' and not necessarily be representative of the general worm population on this enterprise. Accordingly, further testing has been carried out in the 2 years since, in a number of different livestock classes.

The results from 2019 have not been able to be replicated and monepantel appears to be fully effective (>99% efficacy on the basis of WEC reduction) in ongoing monitoring. However, the repeat testing has shown a number of surviving larvae on culture and these have consistently been identified as *Teladorsagia*. This does reinforce the risk that appears to exist in this worm species in this environment, and serves as an ongoing reminder of the importance of providing appropriate refugia and minimizing further selection pressure wherever possible.

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Pain relief in practice

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Introduction

There is increasing pressure from customers and society regarding the conditions under which livestock are managed. Animal Welfare is a broad concept that has been defined in terms of resources provided (e.g. feed, shelter) and/or in terms of animal-based indicators (e.g. health status, behaviour). [1] An individual's animal welfare status is its status in relation to its ability to cope physiologically and psychologically with the situation and environment in which it finds itself. A full discussion of 'animal welfare' is beyond the scope of this paper, which will focus on the specific issue of pain relief, and the concept from the original Five Freedoms of Animal Welfare that an animal should be 'Free from Pain, Injury and Disease'. [2]

Pain

Like 'Animal Welfare', there is a long-standing philosophical discussion into the nature of 'Pain'. We have all experienced pain, but it is quite challenging to describe or define. As a working definition, the International Association for the Study of Pain (IASP) have adopted the following: "*an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage*". [3] Physiologically, the pain perception process can be thought of as having two phases – the initial 'fast pain' whereby the insult is detected (nociception); transmitted to the spinal cord where it is modulated and immediate reflex responses (e.g. withdrawal) are initiated; and projected to the brain, where immediate perception occurs. [4] The complexity of events at the cellular level within both the spinal cord and the brain are beyond the scope of this paper but can have ramifications on a host of body systems including immune function and locomotion, beyond the local effects of tissue damage. Subsequent to the immediate 'fast pain' process is the 'slow pain' associated with the tissue response to the injury. The extent of the tissue response is related to the severity and type of injury sustained, but involves the release of acids and ions from damaged cells, inflammatory mediators such as cytokines, activation of cyclo-oxygenase, lipoxygenase and proteolytic enzymes, these in turn initiate further inflammatory processes, including lymphocyte infiltration, swelling and erythema, all of which contribute to a ramping-up of the painful sensation. In livestock research we are only just beginning to explore the emotional experience associated with pain, and this too is beyond the scope of the current paper.

Pain relief in sheep practice

In Australia, there are two classes of analgesic agent registered for use in sheep – local anaesthetics (LA) and non-steroidal anti-inflammatory drugs (NSAIDs). [5] Local anaesthetics block nerve transmission, so are most effective in the immediate 'fast pain' phase, reducing transmission of the impulses to the spinal cord, so damping down the perception of the pain. By reducing the nervous transmission, they also reduce the development of hyperalgesia – the over-sensitisation of an injured area that can be experienced some 24-48 hours after the insult. The

LA formulations registered for sheep in Australia are Tri-Solfen® (topical application, with cetrimide and adrenaline) and Lignocaine – injectable, either by needle and syringe or using the branded NumOcaine® formulation packaged for use with the NUMNUTS® device. The NSAIDs work mainly by interfering with the cyclooxygenase (COX) or lipoxygenase (LOX) pathways, so are most effective against the delayed 'slow pain' phase. In Australia, there are two registered NSAID formulations for sheep" Ilium Buccalgesic OTM®, which is delivered into the cheek cavity and absorbed via the substantial vascular system there, and Metacam 20® which is an injectable formulation, given subcutaneously. Both contain the same active ingredient, meloxicam.

In an ideal situation, we would apply a multi-modal analgesic approach, using both LA and NSAID to address both phases of the pain response optimising the benefit to the animal.

The future for pain relief in sheep, goat and camelid practice

As veterinarians, the content of our toolkit when addressing painful situations in sheep goats and camelids is limited in terms of registered products. For goats and camelids in particular there are no registered LA or NSAID formulations available. Under the prescribing legislation we are therefore free to make our own judgements on what agents to use, however, we need reliable information on the dose rate, efficacy and safety of potential agents to help us make these decisions, bearing in mind that the metabolism, efficacy and toxicity of agents can differ dramatically between species that are otherwise considered to be 'similar'.

Even for sheep, where registered products are available, adoption of these agents into everyday use on farm is challenged by perceptions of cost without clear benefit, however there are early indications that a production benefit may be offered, particularly in terms of lamb survival and perhaps feed conversion efficiency. [6]

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Why lambs often break their ribs

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Introduction

The presence of calluses and recent rib fractures in lambs at slaughter results in a significant economic loss, estimated to be $3 million per annum to producers and processors in South Australia (SA), and raises concerns about sheep welfare.[1] Occasional reports of fractures in long bones and ribs in sheep have occurred for many years in southern Australia.[2] It was not until the introduction of the Enhanced Abattoir Surveillance (EAS) program by Primary Industries and Regions SA (PIRSA) in 2007 that a reliable estimate of the prevalence in SA could be made.

The EAS program provides feedback to South Australian producers on their consignments (lines) to Thomas Foods International (TFI) of more than 50 sheep (Lobethal abattoirs) or 100 sheep (Murray Bridge abattoirs). Qualified meat inspectors estimate – in 5% increments – carcase prevalence of rib fractures and 20 other conditions and diseases. In lines of sheep under 2 years of age, a prevalence of rib fractures exceeding 5% was common, especially in those lines from the high rainfall regions of the State - Kangaroo Island, the Mid and Lower South East and Adelaide Hills/Fleurieu Peninsula.[3] These trends have remained consistent to 2020.

Bone fractures can be caused by excessive force when handling livestock or by relatively minor trauma if the bones are weak. [4, 5] Nutritional deficiencies have a greater impact on young or pregnant sheep due to the increased requirement for mineral nutrients during growth and lactation, while older and non-pregnant ewes can draw on reserves to cover short-term inadequacies of mineral nutrition. Osteodystrophy may occur as a result of abnormal development, altered mineralisation of formed bone and changes in bone tissue quality and quantity in formed bones. Abnormal bone development, including the development of fragile bones, is often attributed to a lack of dietary minerals or mineral-related imbalances in the diet. The relevant nutrients include copper, molybdenum, sulphur, calcium[6-8] and phosphorus,[9, 10] trace elements such as zinc, manganese, selenium and boron.[11-13] and vitamin D.[14, 15] It may also be caused by overall nutrient deprivation, as well as chronic endoparasitism.[16, 17]

One of the most commonly reported sites of bone fractures in sheep carcases in Australia are the ribs. Each carcase with rib fracture takes additional processing time due to trimming, which results in a downgrading of carcase quality and weight. Despite the economic importance of this disorder, no study has investigated the on-farm circumstances that may contribute to it.

It was hypothesised that rib fracture prevalence in slaughter lambs is a direct result of husbandry practices and is predisposed by nutritional deficiency in ewes and lambs. This study was designed to investigate the association between the prevalence of rib fracture in lambs at slaughter, their nutritional history and the management of the lambs on the farms of origin.

Methods

The study was performed in two stages: an abattoir study in 2016 of the prevalence and descriptive pathology of rib fractures, their geographic distribution and the costs related to the associated carcase trimming and, in 2017, traceback to the properties of origin to investigate possible causal associations. The descriptive pathology and costs associated with rib fracture will be reported in subsequent publications.

Data collection

For the purposes of this study, the term 'lamb' is used for under two years of age, identified in the abattoirs as sheep with no permanent incisors erupted, and the term 'mutton' is used for sheep over two years of age with two or more permanent incisors erupted.

Stage 1 was conducted at an abattoir in the southeast of South Australia during spring, as a higher prevalence of rib fractures in lambs from this region are observed at this time of year. The abattoir study enabled traceback to properties submitting lambs with fractured or calluses on ribs indicating healed or healing fractures. Observations were recorded for 1,268 carcasses with rib fractures from 30,055 lambs in 75 lines processed during the abattoir study in November 2016.

Stage 2 involved tracing the 75 lines to the 60 properties of origin in the southeast of South Australia and western Victoria. Details of animal nutrition, husbandry and management were recorded on 58 of these properties. Soil samples were collected from the paddock primarily grazed by the lambs prior to slaughter on 56 properties and two properties were unable to be sampled. Twenty samples were taken from a transect in each paddock to a depth of 10cm and subsampled for laboratory submission. They were assayed at the Australian Precision Ag Laboratory (APAL) in Adelaide. The assays are listed in Table 1.[18] For 50 lines, liver samples from five lambs were collected by meat inspectors at random in the first 20 of each new line and assayed for copper as described by Paynter.[19] Lambs were considered to be deficient in liver copper reserves if levels were <0.23 mmol/kg wet weight.

Ethics approval

The traceback farm surveys were conducted with approval of the University of Adelaide Human Research Ethics Committee, H-2016-272.

Data analysis

Data analysis was carried out using Microsoft Excel (Microsoft Corp 2011) and R.[20] Spatial and multivariable relationships were examined.

Results

Stage 1 (Abattoir study)

Rib fractures were detected in 1,268 of the 30,055 lambs monitored during the study (4.2%) ranging from 0 -18% across lines of lambs. Fractures were observed in all lines with more than 240 lambs, and in 54 of the 60 (90%) lines monitored.

Eighteen (36%) lines of lambs had rib fractures as well as at least one low liver copper (Table 2). This was significantly different (p=0.02) when compared to the liver copper in the 5 lines that had no rib fractures.

Stage 2 (Property trace-back)

Table 3 summarises the on-farm survey findings and compares them to the rib fracture prevalence observed in lambs at slaughter. Moderate to severe soil acidity ($pH_{water} < 6.2$; $pH_{CaCl} < 5.15$) was evident on 33 (59%) properties and 29 (88%) of these properties presented lambs with rib fractures at slaughter. These findings were highly significant ($p = 0.0001$) when compared to the soil pH on the 5 properties that did not have rib fractures in their lambs at slaughter. Similarly, the result was significant ($p = 0.02$) when the 16 properties that had lambs with rib fractures and soil $pH_{water} > 6.5$ were compared to the 5 properties that did not have rib fractures.

Soil calcium was low on 33 (59%) properties and all except 2 had rib fractures detected in their lambs at slaughter. This was a significant finding ($p = 0.002$) when compared to soil calcium on the 5 properties that did not have rib fractures in their lambs at slaughter. The 2 exceptions were atypical in that they were Dorpers, in contrast to all other lines being Merino, Crossbred or Composite breeds. The lambs from the five properties that did not have rib fractures were all small lines of less than 240 lambs and three lines were Dorpers.

Table 3 also shows eight properties with acceptable soil calcium (60-70% base saturation) and rib fractures in lambs at slaughter were not significantly different (p = 0.051) from the soil calcium on properties without rib fractures, but 12 properties with high calcium (> 70%) were significantly different (p = 0.004).

In addition to soil calcium, properties at risk to copper deficiency, due to either low soil copper or high soil iron and/or molybdenum, were examined in relation to rib fracture occurrence in lambs at slaughter. The soil calcium from 48 properties considered at risk of copper deficiency was not significantly different (p = 0.33) to that in the 5 properties without evidence of rib fractures in lambs at slaughter. However, the soil calcium on properties with rib fractures that were at risk of copper deficiency and had low soil calcium was significantly different (p =0.001) from the soil calcium on properties without rib fractures. In contrast, the soil calcium on 17 properties that applied lime (calcium carbonate) periodically to paddocks and presented lambs with rib fractures was not significantly different (p = 0.44) from the soil calcium on properties that did not apply lime and did not have rib fractures in their lambs at slaughter. An additional 7 properties provided calcium to pre-lambing ewes in the form of loose licks or blocks.

The desired range,[18] mean, minimum and maximum values for key parameters in the soil samples on 56 properties that submitted lines of lambs during the abattoir study are presented in Table 4. Mineral analysis on these soils revealed 12 (21%) with high soil calcium (> 70%), 35 (63%) with low soil copper (< 0.5 mg/kg) and 36 (64%) with high soil iron (> 70 mg/kg) and/or high molybdenum (> 2mg/kg) - all factors known to reduce the availability of copper in grazing ruminants. Additional copper was provided in the form of fertiliser, pre-lambing licks or blocks on 26 (46%) of the properties and this included all five properties where rib fractures were not detected. However, the potential impact of providing an additional source of copper on rib fracture prevalence was not able to be determined.

Regression analysis comparing rib fracture prevalence with soil parameters is presented in Table 5. Significant associations were found between rib fracture prevalence in the 56 lines of lambs at slaughter and iron (p = 0.001), aluminium (p = 0.003), manganese (p = 0.01), calcium (p = 0.004), pHwater (p = 0.02), pHCaCl2 (p = 0.03) and organic carbon (0.03) in the soil samples from where the lambs were grazed prior to slaughter. Minerals that were not found to be significantly associated with rib fracture prevalence included sulphur (p = 0.38) and copper (p = 0.43).

Discussion

The objective of this study was to estimate prevalence of rib fractures detected in lambs at slaughter and relate them to epidemiological factors on the property of origin. An abattoir study (stage 1) was conducted to monitor rib fracture occurrence and traceback to the property of origin (stage 2) for association with potential epidemiological factors. Rib fractures noted during the abattoir study were found to be far more common than previous EAS data implied, and the State-wide distribution indicated that the rib fractures may be due to incidental injury during mustering, handling and transport.

However, a strong association was found between properties at risk to calcium/copper deficiencies and rib fracture prevalence. The much higher proportion of properties detected with rib fractures (90%) in the abattoir study reflects reporting of every carcase with rib fractures in contrast to EAS reporting of estimated prevalence of 5% or above. As a consequence, the EAS data are inevitably an under-estimate of the true prevalence of rib fractures.

The steady rise in the number of lines with rib fractures reported in the first eight years of the surveillance program[3] may reflect inconsistent monitoring rather than increasing prevalence. However, the peak of 9,455 detections in 2016 coincides with the wettest year in South Australia for over 20 years. This may be due to an increased risk of copper deficiency: in wet years copper availability to the grazing animal can be reduced by an increased availability of other elements particularly molybdenum.[21] However, this is only one of several possible explanations for the higher prevalence. The much lower detection of rib fractures in lines of sheep over two years of age (15%) is most likely due to increased bone strength and resilience with age.

A limitation with this study is sample size as there were only six lines without rib fractures. They were all small lines of less than 240 lambs compared to the study average of 506 lambs per line. Three of these small lines were also Dorpers whereas all other lines were either Merino, Crossbred or Composite lambs. It is unknown if breed or line size had an influence on rib fracture detection.

The significant correlations in Table 5 between rib fracture prevalence and soil iron, aluminium, manganese and pH are predictable as these soil parameters are all indicators of acidic soil conditions. Similarly, the association between rib fracture prevalence and low soil calcium and organic matter is concomitant with acidic soil conditions. The significant association identified between increased rib fracture prevalence and high calcium and pH is also predictable as these conditions reduce the availability of several macro and trace elements including copper in grazing ruminants.

In contrast, 48 (86%) properties where sheep were adjudged at risk to copper deficiency, based on soil assays, did not show a significant ($p = 0.33$) association with rib fracture prevalence (Table 3) and soil copper was not correlated ($p = 0.43$) with rib fracture prevalence (Table 5). This is not unexpected as copper availability may be reduced by an excess of calcium, iron, sulphur, molybdenum, zinc and cadmium. It is also notable that 27 of the 33 properties that provided calcium and / or copper supplements had rib fractures in their lambs. Haphazard supplementation was noted during the on-farm survey and a more strategic and targeted supplementation approach is indicated in order to impact rib fracture prevalence.

Conclusion

The significance of rib fractures in lambs in South Australia and western Victoria has been demonstrated and supports EAS findings. Based on the significant associations identified on-farm with the occurrence of rib fractures, it is anticipated the prevalence could be dramatically reduced if preventative strategies were introduced on-farm. Strategies could include addressing physical causes of incidental injury during husbandry procedures as well as improved nutrient monitoring and more efficient and effective calcium and copper supplementation on at-risk properties. This would require a concerted awareness and incentive program for lamb producers but has the potential to substantially improve lamb growth rates and welfare as well as saving the red meat industry several million dollars annually in South Australia alone. The opportunity in other lamb producing States is expected to be similar but has not been investigated.

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Conflict of interest

The authors declare no conflict of interest

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Table 1: Soil assays performed by the Australian Precision Ag Laboratory (APAL) as described by Peverill, Sparrow and Reuter [18]

Soil parameter	Rayment and Lyons Assays using ICP-OES
pH	4A1- 1:5 soil/water extract; 4B1 – 1:5 soil/0.01M calcium chloride extract
Organic Carbon	6A1 Walkley and Black
Phosphate	9B2 Colwell 0.5M sodium bicarbonate pH 8.5 solution at 1:100 16 hours
ECEC	15J1 – Effective CEC is the sum of exchangeable cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) plus exchange acidity (Al^{+++}, H^{+})

Calcium	15D3 1M ammonium acetate solution at pH 7.0 at 1:10
Magnesium	15D3 1M ammonium acetate solution at pH 7.0 at 1:10
Potassium	15D3 1M ammonium acetate solution at pH 7.0 at 1:10
Sodium	15D3 1M ammonium acetate solution at pH 7.0 at 1:10
Sulphur	10D1 0.25M potassium chloride solution at 4.5:30
Aluminium	15G1 1M KCl solution at 1:10 extraction
Iron	12A1 DTPA
Copper	12A1 DTPA
Boron	12C2 0.01M hot calcium chloride, 1:2 soil:extract
Manganese	12A1 DTPA
Molybdenum	0.3M ammonium oxalate extraction (Tamms reagent)

Table 2: Student t-test analysis showing number of lines (n), mean, minimum, maximum, standard error (SE) and P value for lines of lambs with no rib fractures (no RF) detected at slaughter compared with lines of lambs that had rib fractures (RF), or rib fractures >5% prevalence in regard to low liver copper (Cu) in 56 lines from south east South Australia and western Victoria.

Parameter	n	Mean	Minimum	Maximum	SE	P value
Liver Cu & No RF	5	1.2	0.3	2.3	0.84	--
RF + low liver Cu	18	0.56	0.19	1.4	0.39	0.02
RF >5% + low liver Cu	8	0.49	0.21	0.9	0.23	0.04

Table 3: Student t-test analysis showing number of lines (n), mean, minimum, maximum, standard error (SE) and P value in lines of lambs with no rib fractures (No RF) detected at slaughter compared with lines of lambs that had rib fractures (RF) with regard to: low and high soil pH(water); low soil exchangeable calcium (Ca); normal to high soil calcium; and at risk to copper deficiency and low soil calcium in 56 lines from south east South Australia and western Victoria

Parameter	n	Mean	Minimum	Maximum	SE	P value
Soil pH & No RF	5	6.51	5.65	7.87	0.83	--
RF + soil pH < 6.2	29	5.72	5.15	6.15	0.25	0.000
RF + pH > 6.5	16	7.34	6.59	8.52	0.59	0.02
Ca & No RF	5	63.2	50.2	87.3	14.65	--
RF + at risk to Cu deficiency	48	57.1	33.2	84.2	13.22	0.33
RF with normal Ca	8	64.7	61.7	69.7	2.55	0.81
RF with low Ca	31	49.3	33.2	59	7.32	0.002
RF with normal/high Ca	20	73.3	61.7	86.9	8.06	0.051
RF with high Ca	12	79.0	73.9	86.9	4.38	0.004
RF with low Ca + low Cu	31	49	33.2	59	7.48	0.001
RF + lime ($CaCo_3$) application	17	57.7	33.2	84.2	14.25	0.44

Table 4: Summary of soil test results showing the units, number of sheep properties represented (n), percentage of total properties (%), desired range, mean, minimum and maximum for each soil parameter on the 56 properties in south east South Australia and western Victoria.

Soil parameter	Units	n	%	Desired	Mean	Min	Max
Iron	mg/kg	56	100	10-70	156	6.8	538
Iron > 70	mg/kg	34	61				
Exchangeable Aluminium	%	56	100	< 1.5	0.8	0.0	6.7
Sulphur	mg/kg	56	100	20-40	8.6	1.5	49
Molybdenum	mg/kg	56	100	0.8-2.0	0.6	0.1	2.3
Molybdenum > 2	mg/kg	2	3				
Copper	mg/kg	56	100	0.5-5.0	0.4	0.1	1.0
Copper < 0.5	mg/kg	35	63				
Copper 0.5 - 5	mg/kg	8	14				
Manganese	mg/kg	56	100	5.0-50.0	6.3	0.6	22.0
Exchangeable Calcium	%	56	100	60-70	73	50	91
Exch Ca > 70	%	12	21				
pHwater		56	100	6.0-6.5	6.3	5.2	8.5
pHCaCl		56	100	5.0-5.5	5.5	4.2	7.7
Organic Carbon	%	56	100	2.0-5.0	2.6	0.6	5.5

Table 5: Estimated regression coefficients, standard errors (SE) and P values for several soil parameters compared to rib fracture prevalence on 56 properties in south east South Australia and western Victoria.

Soil parameter	Units	Estimate	SE	P value
Iron	mg/kg	0.0001	0.00003	0.001
Exchangeable Aluminium	%	0.01	0.003	0.003
Sulphur	mg/kg	0.0006	0.0007	0.38
Molybdenum	mg/kg	0.005	0.009	0.63
Copper	mg/kg	0.02	0.02	0.43
Manganese	mg/kg	0.003	0.001	0.01
Exchangeable Calcium	%	-0.001	0.0003	0.004
pH_{water}		-0.01	0.006	0.02
pH_{CaCl}		-0.01	0.005	0.03
Organic Carbon	%	0.009	0.004	0.03

Secondary copper poisoning in ewes on subterranean clover

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Introduction

'Toxaemic jaundice' due to secondary copper poisoning has been an important cause of ewe mortality in NSW flocks for almost a century. Secondary copper poisoning occurs despite normal dietary intakes of copper whereas primary copper poisoning occurs on diets high in copper or from treatment overdoses. Sheep, and particularly some British breed sheep, are the most susceptible domestic species. They readily absorb copper but have difficulty in excreting high levels, so accumulate it in the liver. When secondary copper poisoning occurs in sheep with concurrent liver disease, (which exacerbates this predisposition), it is referred to as hepatogenous chronic copper poisoning. Secondary copper poisoning, in the absence of liver disease, most notably on subterranean clover (*Trifolium subterraneum*) based pastures that are molybdenum deficient, is referred to as phytogenous chronic copper poisoning.

While copper accumulation is usually chronic, deaths occur from an acute haemolytic crisis.[1,2] This paper describes an outbreak of copper poisoning in British breed cross ewes on clover dominant pastures, with or without chronic liver disease on five properties on the Central Tablelands of NSW, between late October 2020 and early February 2021.

Case reports

All cases occurred in large commercial prime lamb operations. Four of five ran self-replacing composite ewe flocks while the other flock were first-cross ewes purchased three years previously. In most cases ewes were found dead. If seen before death, affected ewes were usually dull, separated from the mob, sometimes with head pressing and trembling before collapsing and dying. Sick ewes had pale, brownish mucous membranes. On necropsy most ewes were in fat condition with pale yellow to orange body fat, brownish liver and lungs, swollen and black kidneys and red brown urine.

Laboratory findings supported the diagnosis of copper poisoning, toxaemia and a haemolytic crisis. Liver and kidney copper levels were elevated (Table 1). Liver enzymes were also elevated consistent with hepatobiliary injury. There was azotaemia consistent with renal damage and anaemia as expected in a haemolytic crisis.

Histological findings from all livers examined showed evidence of hepatocellular degeneration and necrosis, with hepatocytes and macrophages containing brown pigment indicative of copper accumulation. In some cases, there were minimal chronic changes indicative of exposure to hepatotoxic plants and pyrrolizidine alkaloids (PAs). In other samples however, there were changes consistent with mild to moderate exposure to pyrrolizidine alkaloids.

Kidney histology demonstrated acute, severe tubular injury and necrosis. A lung sample collected from a ewe on property 5 showed multifocal oedema with no other significant findings.

Liver and kidney samples from all properties contained elevated copper levels (Table 1).

	Kidney copper levels (0.00 – 0.20 mmol/kg wet weight)	Liver copper levels (0.23 – 3.67 mmol/kg wet weight)
Property1	0.75 mmol/L	7.15 mmol/L
Property 2	0.49 mmol/L	
	1.01 mmol/L	9.76 mmol/L
Property 3		5.50 mmol/L*

	1.11*mmol/L	1.04*mmol/L
Property 4	0.82 mmol/L	7.87 mmol/L
Property 5	1.09 mmol/L	6.59 mmol/L

Table 1. Tissue liver and kidney copper levels. Samples from property 3 were markedly autolysed. The laboratory comment that under these circumstances' significant loss of copper from the tissue fraction is expected.

Treatment

On the first three properties affected ewe mobs were drenched with a mix of sodium sulphate and sodium molybdate consistent with an Australian Pesticides and Veterinary Medicines Authority (APVMA) permit as described by Edmonstone.[3] On the first two properties, loose mixes as described in the AVPMA permit were also tried. On properties four and five, as losses appeared to be waning, ewes were not treated.

Discussion

'Toxaemic jaundice' has been a major cause of ewe mortality in NSW flocks since the late 1920's. In some areas it appeared following the widespread establishment of subterranean clover in the late 1930's and in others following the proliferation of common heliotrope (*Heliotropium europeaum*) and Paterson's curse *(Echium plantagineum)*. Such was the problem that in 1936 a multijurisdictional committee was initiated to investigate with its final report published in 1956.[4] The committee member noted that chronic copper poisoning seen on an irrigated property in Victoria following the 'over-liberal' application of copper sulphate for fluke control, 'appeared to be indistinguishable from the disease called toxaemic jaundice'. It was realised that toxaemic jaundice occurred on pastures (usually subterranean clover dominated) with normal amounts of copper. In some cases, there was evidence of severe liver damage consistent with pyrrolizidine alkaloidosis but in some cases the liver showed histological evidence of acute injury only.

The Committee concluded that there were three diseases within the toxaemic jaundice complex. The first was a 'special form of chronic copper poisoning' (phytogenous chronic copper poisoning), the second was heliotrope poisoning and the third was heliotrope-chronic copper poisoning (hepatogenous chronic copper poisoning). Seawright[5] considered that elucidating the mechanism behind the toxaemic jaundice complex 'stands as one of the great achievements of Australian veterinary science.' However, as noted by Salmon[6] and in the experience of the author, liver failure due to heliotrope poisoning can occur without copper accumulation and subsequent 'toxaemic jaundice.'

The Committee noted that phytogenous chronic copper poisoning is relatively rare in most of Australia. They however noted a case with 20% mortality in cross bred ewes grazing abundant clover pastures that followed exceptional autumn and winter rains in 1946. Keast[7] reported that on subterranean clover pastures in endemic areas such as the Southern Tablelands, a few cases of copper poisoning occurred each year but that most properties running crossbred sheep on improved pastures experienced losses in years of luxuriant clover growth.

In the experience of the author, hepatogenous chronic copper toxicity is far more common than phytogenous chronic copper poisoning on the central western plains of NSW, a view shared by Salmon in the Riverina (Salmon D, pers comm). Records from the then Wagga Wagga Regional Veterinary Laboratory noted that between 1977 and 1996, of 5577 submissions from sheep for which histopathological findings were recorded, 165 had copper poisoning diagnosed. Of these, 22 were recorded as hepatogenous and 4 as phytogenous. There were 2 phytogenous cases in 1992 and one each in 1993 and 1995. However, phytogenous chronic copper poisoning was more common in good springs in the area bounded by Young, Gundagai and Cootamundra (Glastonbury J, pers comm.).

While chronic copper poisoning of any type is uncommon on the Central Tablelands, with the benefit of hindsight outbreaks were predictable in 2020, an exceptional year for clover growth following the breaking of the prolonged drought in early autumn of that year. In all cases reported here, the ewes were grazing improved phalaris and cocksfoot pastures that in 2020 were dominated by subterranean clover. In all cases there was minimal to no pasture contamination with weeds containing pyrrolizidine alkaloids (most notably Paterson's curse, common heliotrope and blue heliotrope (*Heliotropium amplexicaule*). Ewes on four of five flocks were homebred while the first cross ewes in case three were purchased from central Western NSW three years previously.

While there was some evidence of chronic liver damage caused by PAs, none of the ewes had a history of exposure in at least the previous three years. This appears to be an outbreak of phytogenous copper presumably caused by relatively high pasture copper and relatively low pasture molybdenum and sulphur levels.

In sheep, the rate of copper accumulation is controlled by dietary copper, molybdenum and sulphur. Rumen microorganisms convert sulphates to sulphides which then bind with molybdenum to form thiomolybdates. These then combine with copper to form insoluble copper-thiomolybdates, limiting the uptake of dietary copper. Poisoning has occurred on pastures with a relatively low copper content (15-20 ppm) when pasture molybdenum levels are very low. Ideally the diet of sheep should contain a copper to molybdenum ratio of 10:1.[1]

Monitoring of these levels is planned for the spring of 2021 although at this stage pastures have become grass dominant so the risk in 2021 is anticipated to be low.

Fortunately, measures recommended to prevent phytogenous chronic copper poisoning are also consistent with good pasture management. The periodic use of fertiliser containing molybdenum is recommended to assist plants to synthesise amino acids from nitrates and to enable *Rhizobium* bacteria in clover root nodules to fix atmospheric nitrogen.[8] Liming of soils to reduce acidification improves pasture growth as well as making molybdenum more available. As grasses are higher in molybdenum and lower in copper than clover, restoring perennial grass pastures with a component of clover has numerous benefits including improving the balance of copper and molybdenum. If producers had the option, they should avoid grazing British breed or crosses on lush subterranean clover dominant pastures on acid soils and if they have no choice to supplement with loose mixes containing molybdenum and sulphur as described in the APVMA permit.

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