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Putting science into practice

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Assessment of changes in lamb activity before and after lamb marking using accelerometers

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Introduction

Commercial technologies are rapidly becoming available which will enable the continuous monitoring of individual animals in real time. Accelerometers measure animal activity, and allow designation of animal behaviours such as standing, walking and lying. There are many applications of such technologies in both the animal health and animal welfare areas.

In a preliminary study, accelerometers were applied to lambs prior to lamb marking, and the impact of lamb marking procedures were assessed from accelerometer data, both with and without pain relief[1].

Methods

Composite breed (n = 50) and Merino (n = 50) ram lambs from commercial-sized mobs were tagged and an accelerometer (AX3; Axivity, UK) placed on the inside of the rear leg 5 days prior to lamb marking. The accelerometers were held in place by use of elastic adhesive bandage (Askina Plast E, 7.5 cm), and in the case of the Composite lambs, and additional tape (Rocktape, 5cm x 5cm) was used to secure this. Lambs were systematically allocated to treatment (pain relief or control) after blocking for weight. Lambs assigned to the pain relief group received a subcutaneous injection with Metacam® 20 mg/ml solution for injection (Boehringer Ingelheim, North Ryde, Australia) prior to marking procedures and Control lambs received no pain relief. Lambs were then tail docked using a gas knife and castrated using an Elastrator® ring. Following marking, ewes and lambs grazed pasture in large paddocks and the accelerometers were removed within 2 weeks of marking.

Activity level was determined in 24-hour intervals, with the main measure being the mean standard vector magnitude (SVM), which indicates degree of movement intensity.

Results and Discussion

Accelerometer data was only available for 29 Composite lambs (18 Control and 11 Treatment) and 29 Merino lambs (16 Control and 13 Treatment). For the Composite lambs, retention rates of accelerometers was high (100%) but battery discharge occurred on some of the devices where they were used for the first time. For the Merino lambs, poor retention resulted in only being able to collect data from 29/50 lambs. The Merino ewes and lambs were placed in an oat crop and had access to vineyards, and so physical dislodgement is expected to be the main problem.

The accelerometers did detect a definite change in activity as a result of lamb marking, with lambs spending more time standing and less time lying, Treatment differences were difficult to detect and were not always consistent. For Composite lambs, there was no effect of treatment ($p = 0.345$). In the Merino lambs, the interaction of day and treatment was significant ($p = 0.029$), with the main difference being Treatment lambs spent less time standing. The low number of lambs from which data was recorded, and using 24 hour time periods for the analysis, reduced the ability to adequately analyse data.

For Composite lambs, SVM peaked on the day of marking (mean 90) and declined for three days (mean 26). For Merino lambs, SVM also peaked at lamb marking (53) and was lowest in the 2 days post-marking (30 and 31 respectively).

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Reference

1. S. McGrath, J. Chapman, J. Broster, B. Allworth, G. Kelly. Assessment of changes in lamb activity before and after lamb marking using accelerometers. Animal- Science Proceedings 2023; 14:59-60. doi: 10.1016/j.anscip.2023.01.084

Pestivirus studies in sheep

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While there is considerable knowledge on pestivirus in cattle (BVDV), and a vaccine (Pestiguard, Zoetis) to assist control, pestivirus in sheep (Border Disease, BDV) is less well researched and control strategies are based on epidemiological data from cattle. Several producers in southern NSW have had BDV diagnosed in their sheep flocks and have sought assistance in controlling the disease, and have queried whether the cattle vaccine would assist in sheep flocks. Overseas studies have suggested cattle vaccines are not protective in sheep, leaving deliberate exposure of young sheep as the most logical way to control BDV in infected flocks.

Methods

Two small sheep studies were undertaken as part of a final year Honours project. The first study was a dose and safety study on the use of the cattle vaccine Pestiguard (Zoetis) in sheep (Vaccine study). The second study involved the deliberate exposure of naïve sheep to known PI animals for 2, 7 or 15 days (Exposure study). In the Vaccine study, 70 Merino ewe hoggets were randomly allocated to one of four groups: Group 1 – 0.5 ml Pestiguard (1/4 dose), n=20; Group 2- 1 ml Pestiguard (1/2 dose), n=20; Group 3- 2 ml Pestiguard (full dose), n=20; Group 4- no vaccine (Control). Those in the vaccine groups (Groups 1-3) received two doses of vaccine at the designated rate 6 weeks apart. Sheep had body temperatures recorded for 3 days post vaccination and also had antibody levels assessed. In the second study, 75 Composite ewes were systematically allocated to one of three groups and were deliberately exposed to two PI lambs for either 2, 7 or 15 days. Antibody responses in the exposed ewes were assessed 22 to 43 days post exposure. An additional 10 ewes which were not exposed to the PI lambs were also antibody tested to ensure no other exposure could have occurred.

Results and Discussion

The cattle vaccine appeared to be safe in the small number of sheep vaccinated, and the full cattle dose (2 ml) was considered the optimal dose for sheep. While sheep developed BVDV antibodies, as would be expected from administration of a BVDV vaccine, the level of cross protection for BDV was low, and antibody levels were unlikely to be protective. In the Exposure trial, only 3 of 66 previously naïve sheep demonstrated seroconversion. This demonstrated a very low rate of transmission and suggested that deliberate exposure to PI lambs at low-risk times for less than 15 days was not likely to be an effective means of achieving seroconversion throughout a flock and therefore not provide protection against BDV challenge during gestation.

A paper "An investigation into the transmission and control of pestivirus in sheep in Australia. Prell MM[a], McGrath SR[a], Kirkland PD[b], Allworth MB[a] " has been submitted to the Australian Veterinary Journal for publication.

The assistance of Shawn McGrath, Peter Kirkland and Sally Oswin in this work is gratefully acknowledged.

A case for integration of virtual sheep extramural studies to be added to preclinical extramural studies

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Relatively few students entering Australian veterinary schools have previous sheep enterprise experience[1]. This can particularly be the case for international students where limited contact with small ruminants is available in some countries. Many students educated in Australia also have minimal contact with sheep production systems and limited knowledge from primary and secondary education[2]. An important part of students gaining a practical understanding of sheep production systems is spending time on sheep enterprises during work integrated learning (WIL), more commonly known as animal husbandry extra mural studies (AHEMS) in veterinary teaching. During COVID lockdowns additional methods of student training were developed to continue learning without access to external enterprises and often without direct access to the University. This required the development of online material for AHEMS and was achieved using a previously developed online tool called DookieVR, allowing viewing of the Dookie sheep enterprise through seasons and across multiple areas of the farm. This site was integrated with other videos and text and small Zoom discussion groups using the learning management system Canvas. Two academic staff were required to manage the week of online learning with an enrolment of 170 students from 6 veterinary schools across Australia. This was aided by significant use of peer feedback with student groups submitting and reviewing assessment tasks for each day of the week. Student test performance increased from commencement to completion of the week by an average of more than 14% and written student feedback on the week was positive. 56 students responded to a survey at the end of the week to provide feedback on demographic information and their experience in the week of virtual AHEMS. The mix of students was diverse with students who had previously completed some AHEMS and some students who had not done any AHEMS previously. The ratio of female to male respondents was close to the overall class ratio at 15% male and 85% female students. Over 80% of students responded that they had a better understanding of the current and potential role of the veterinarian in the sheep industry at the end of the week. For those students who had already completed some AHEMS placements more than 80% agreed these placements assisted them in making important career decisions or helped to decide what they might do after graduation. As anticipated, the majority (54%) of students who had completed on-enterprise AHEMS prior to virtual suggested that virtual AHEMS was a poorer experience. However, 21% of students who had completed work stated that virtual was better. This most probably demonstrates the variability in on-enterprise placements. This early data suggests that there may be a case for the integration of virtual EMS to bridge the gap between class-based theory and initial enterprise-based placements to improve student and enterprise outcomes associated with AHEMS. More work is required to review the benefits and challenges of this use of virtual training.

1. Feakes, A.M.; Palmer E.J; *et.al*.; 2019; Predicting career sector intent and the theory of planned behaviour: survey findings from Australian veterinary science students, *BMC Vet Res* **15**, 27 (2019) https://doi.org/10.1186/s12917-018-1725-4
2. YouthInsight; 2020; PIEFA Student Report – FINAL, https://www.piefa.edu.au/wp-content/uploads/2022/10/piefa_student_survey_final_report.pdf

Updates on sheep, goat and camelid health and biosecurity projects at Animal Health Australia

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Animal Health Australia (AHA) works with its members to deliver a number of projects in livestock health and biosecurity (in addition to the significant emergency animal disease (EAD) role that it has).

The National Sheep Health Monitoring Project (NSHMP) has been in place since 2007 and around 90 million sheep have been inspected as part of the project for up to 19 conditions. A number of new initiatives have been implemented in the project to improve data collection, reporting, and extension to producers to help them to be able to act on the animal health feedback they receive on their consigned sheep. One part of this has been the 'Sheep Health Conditions – Carcass Impacts' virtual reality tool (https://animalhealthaustralia.com.au/sheep-carcass-conditions-vr-tool/). This tool demonstrates the effects of six conditions (pleurisy, grass seeds, rib fractures, arthritis, sheep measles, and vaccination lesions) to show the impact of them as well as provide information for producers on what causes them and how to manage them on farm.

AHA has been working with Integrity Systems Company (ISC) on the 'myFeedback' portal which will allow producers to access their sheep health data, along with MSA and carcase yield data, where available. This will launch soon and replace the existing Livestock Data Link program.

Research has also been carried out investigating the possible causes of some of the more prevalent conditions that are found in the NSHMP. Joan Lloyd investigated the pathogens occurring in pneumonic lungs at abattoirs in four states (reported at the 2021 SCGV Conference) and a recent study has started investigating the relatively high incidence of nephritis/nephropathy in abattoirs (there was an early report from Luzia Rast of CSU at the 2022 SCGV Conference).

AHA is working with Sheep Producers Australia and WoolProducers Australia to help deliver the National Sheep Industry Biosecurity Strategy (NSIBS). This Strategy will be reviewed before the end of the current project period (June 2024). One of the ongoing activities is the Tasmanian Health Monitoring and Biosecurity project (report by Bruce Jackson at the 2022 SCGV Conference). Another output from the project was the Sheep EAD augmented reality (AR) app which launched in 2022 and is available in the Apple, Google, and Microsoft app stores. It can be used on mobile devices (and the HoloLens) to help producers (and other stakeholders) recognise the signs of four EADs affecting sheep – foot and mouth disease, sheep pox, bluetongue, and scrapie.

Market Assurance Programs (MAPs) have been in place for sheep and goats for decades. The GoatMAP has recently undergone a major revamp and now includes caprine arthritis encephalitis (CAE) as an additional disease. The original program has been split into biosecurity, Johne's disease (JD) and CAE modules, with participants required to do the GoatBIO module but able to choose to do either or both of the disease modules. A new testing pathway is also available for the CAE module, using the milk test that was developed by the Elizabeth Macarthur Agricultural Institute (EMAI) in NSW. Information on the new program is available on the AHA website (https://animalhealthaustralia.com.au/goatmap/).

AHA has also been working with the Australian Alpaca Association on developing a traceability system for alpacas. This long-term effort has recently seen successes with two electronic ear tags being approved for use in alpacas, National Livestock Identification System (NLIS) Business Rules agreed for alpacas (and llamas), and functionality now in place in the NLIS database for recording movements of alpacas. This system will be voluntary for now, but the AAA would like it to become mandatory in future. More information is available on the AAA website (https://alpaca.asn.au/nlis/).

Chlamydia pecorum as a reproductive pathogen in sheep: insights into epidemiology, risk factors, diagnostics and molecular characterisation

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Abstract
Ovine abortion and perinatal mortalities associated with *Chlamydia pecorum* have been increasingly reported in recent years. However, there are still knowledge gaps in our understanding of *C. pecorum* epidemiology, impacts for Australian sheep producers, and strategies for treatment or control. Here we provide a summary of reported cases of *C. pecorum*-associated reproductive losses across Australia and New Zealand and discuss risk factors for disease. Findings from *C. pecorum* molecular characterization studies using DNA detected in samples from aborted and stillborn lambs and the implications for disease investigations and potential control strategies are presented.

1.1. Introduction
Chlamydia pecorum is a common gastrointestinal inhabitant of clinically healthy sheep but is also capable of causing disease. *Chlamydia pecorum* has been recognised as a cause of arthritis [1-3] and keratoconjunctivitis [4] in sheep. Sporadic abortion outbreaks associated with *C. pecorum* have been reported [2,5,6]. However, there have been advances in the reporting of the abortigenic potential of *C. pecorum* in sheep across several regions in Australia and New Zealand over the past five years.

1.2. Historical reports of *Chlamydia pecorum*
It is difficult to trace reports of *C. pecorum*-associated reproductive losses in the literature because of changes to nomenclature over time. However, sporadic cases of *Chlamydia*-associated foetal and lamb mortalities have been reported in Australian since the 1960s. Rofe [7] and Seaman [8] both reported cases of chlamydial abortion in sheep in New South Wales, including one case involving maiden ewes. Other reports described isolated cases where the "psittacosis-lymphogranuloma agent responsible for enzootic abortion of ewes" or observations of elementary bodies in tissues from aborted or stillborn lambs suggestive of *Chlamydial* aetiology [9-13]. It is unclear if the chlamydial species identified in historical reports would be consistently characterised as *C. pecorum* using current nomenclature and molecular diagnostic methodology.

1.3. Recent reports of abortions and stillbirths associated with *Chlamydia pecorum*
In the past five years, disease investigations for *C. pecorum* have been described in more detail with increased detection in cases of abortion and perinatal lamb deaths in sheep flocks across Australia and New Zealand. Table 1 provides a summary of *C. pecorum* cases associated reproductive losses over the past five years. Some of these cases have been reported in scientific literature, whilst others are unpublished data sourced from state veterinary laboratories. In the majority of investigations, other endemic and exotic pathogens were excluded.

Table 1. A summary of cases of *Chlamydia pecorum*-associated reproductive losses in sheep flocks from Australia and New Zealand from 2018 to 2023.

Western Australia

2018-2019 Observational research project: *C. pecorum* detected in 15/35 aborted and stillborn lambs on 5/6 farms in southern WA as part of an observational research project. In affected flocks, mid- to late-term abortions, stillbirths and retained foetal membranes were observed.^ [14]

2021 Field investigation: sporadic abortions (6/248 ewes) detected at pregnancy scanning in ewe lambs on the south coast of WA. *C. pecorum* detected on vaginal swabs taken from ewes with evidence of abortion at pregnancy scanning. No aborted material was collected.^

2021 Field investigation: sporadic abortion in mixed age Merino ewes on the south-east coast of WA. Two aborted foetuses recovered. Farmer observed one ewe abort mid-way between pregnancy. *C. pecorum* detected in aborted material.^

New South Wales

2018-2020 Field investigations: *C. pecorum* was diagnosed as a cause of late term abortions, stillborn lambs and lambs born alive, weak and premature in ewes on five properties located across NSW. Aborted lambs were observed as early as one month prior to the expected commencement of lambing to 10 days after lambing commenced. Foetal and lamb losses were in most cases estimated at 20–30%.^ [15-17]

Tasmania

2020 Field investigation: 10% abortion rate in maiden Coopworth X ewes. *C. pecorum* detected in aborted material.^

South Australia

2020 Observational research project: Abortion outbreak, 50% of maiden ewes aborted in study flock. *C. pecorum* detected in 4/30 vaginal swabs from aborting ewes, but not detected in aborted foetuses.

Victoria

2018 Field investigation: 40/1000 ewes aborted near term. *C. pecorum* detected in aborted material from 2 ewes.

2019 Field investigation: Sporadic abortion occurring 3 weeks before term. *C. pecorum* detected in aborted material.

2020 Field investigations:

- 15/7500 late term abortions in mixed aged ewes. *C. pecorum* detected in aborted material from 2 ewes.
- 14/100 mixed aged ewes aborted in late gestation. *C. pecorum* detected in aborted material.
- 10/2400 mixed age ewes aborted in late gestation. *C. pecorum* detected in aborted material from 3 ewes.

2023 Field investigation: History of poor reproductive outcomes in ewe lambs over the past 3 years. Mid-pregnancy losses observed in 250/3000 ewe lambs, confirmed by sequential ultrasounds. *C. pecorum* detected in aborted material from 3 ewes.

New Zealand

2018 Field investigation: South Island: Romney ewe flock. 340/2989 ewes aborted in the last ~6 weeks of gestation. *C. pecorum* detected in aborted material.[18]

2019 Field investigation: South Island: *C. pecorum* detected in three abortion outbreak investigations.^

2020 Field investigations:

- North Island: 3 lambs submitted from a 2000 head flock experiencing maiden ewe abortions for several years. *C. pecorum* detected in aborted material.[19]
- North Island: up to 20% losses from 1100 maiden ewes. *C. pecorum* detected in aborted material.^ [19]

^ Sequence type (ST) 23 *C. pecorum* strain confirmed with genotyping [14,17,20].

It is evident that infection with *C. pecorum* can be associated with a range of adverse reproductive outcomes. *Chlamydia pecorum* related abortions can occur from mid- to -late pregnancy and may be sporadic or occur in outbreaks. There was no indication that clinical illness (other than reproductive disease) was observed in the affected ewes. Anecdotally, ewes that abort were reported to have similar scanning and marking rate in subsequent pregnancies compared to unaffected ewes, but further research is required to confirm this.

1.4. Molecular epidemiology and strain variation

There are genetically diverse strains of *C. pecorum* recognised in a wide range of host species. Recently, strains associated with abortion and perinatal lamb mortality have been characterised [14,17,20]. Multilocus Sequence Typing (MLST) and *omp*A genotyping has demonstrated clonal sequence type (ST)23 as the most commonly identified strain of *C. pecorum* detected from abortions and perinatal lamb mortality in sheep from Australia and New Zealand.

C. pecorum ST23 strains associated with abortions and stillbirths are genetically identical to "pathogenic" strains detected in cases of *C. pecorum*- associated arthritis, conjunctivitis and sporadic bovine encephalomyelitis, but dissimilar to "non-pathogenic" enteric strains [14,20]. This indicates that one of the major determinants of the clinical outcome of *C. pecorum* infection is pathogen strain and the *C. pecorum* ST23 strains appear endemic across Australia and New Zealand. Therefore, characterising *C. pecorum* strain type is helpful in abortion investigations by differentiating *C. pecorum* ST23 from enteric strains which are more likely to be incidental contaminants. This is especially important where histopathology (and immunohistochemistry) on foetal tissues is not available. The inclusion of genotyping as standard methodology for abortion cases where *C. pecorum* is detected is being adopted by some veterinary laboratories in Australia.

Whole genome sequencing (WGS) of several abortigenic *C. pecorum* ST23 strains from Australian sheep revealed unique features, including deletion in the CDS1 of the chlamydial plasmid [20]. A further unique deletion was noted in a polymorphic membrane protein gene (*pmp*G) that suggests further investigation, given the role of PmpG in host cell adherence and tissue tropism, is warranted [17]. Increasing the number of available *C. pecorum* genomes may identify other informative regions for fine-detailed characterisation of strains and/or lineages. This has implications for developing refined protocols for disease diagnosis, provide further insights into the virulence factors and diversity that may impact disease severity, and can be used to identify suitable peptides for vaccine development.

1.5. Transmission

There are limited epidemiological studies investigating the transmission of *C. pecorum* strains associated with disease. The faecal-oral-route has been suggested as a likely transmission route for enteric strains of *C. pecorum*. However, it is unclear if ST23 has a similar transmission pathway. One experimental study reported oral infection with *C. pecorum* failed to result in placental colonisation, however it is unclear which strain was used in this study [21]. It is possible that "pathogenic" strains of *C. pecorum* have mechanisms that allow dissemination from the gastrointestinal tract to other tissues. Some authors have suggested concurrent infection with other organisms may cause enteric chlamydiae to be able to colonize the placenta [21].

Chlamydia pecorum has been detected in the kidneys of experimentally infected sheep and aborted foetuses, suggesting potential for urinary shedding [1,14]. In the same studies, *C. pecorum* was detected in the lung of aborted foetuses, but not in experimentally affected adult sheep. This suggests that dispersal of *C. pecorum* into the amniotic fluid and subsequent aspiration by the foetus may play a role in the transmission of *C. pecorum* to the foetus during pregnancy. Airborne spread via respiratory secretions is probably low in adult sheep, but further studies are required to confirm if this is the case for *C. pecorum* ST23. *C. pecorum* ST23 has also been detected in conjunctival swabs suggesting mucosal infection may play a role in transmission and ocular secretions as a source of infection for other sheep.[4]

Viable *C. pecorum* detected by the culture of *C. pecorum* from aborted material [16] suggested aborted material could represent an opportunity for point source infection. Furthermore, *C. pecorum* ST23 has also been detected in vaginal, conjunctival and rectal swabs of naturally infected sheep [20]. It is so far unclear the duration and level of shedding that occurs at these sites. The detection of ST23 strains in vaginal, conjunctival and rectal swabs of ewes with successful pregnancies suggests a carrier state exists. The role of venereal transmission or ram infection has not been investigated. However, semen shedding for the closely related *C. abortu*s has been reported in ruminants [22] and *C. pecorum* has been detected in the urethra of male koalas [23]. So, it is plausible that rams play a role in transmission of *C. pecorum* and further investigation is warranted.

The role of carrier sheep, other livestock or wildlife species as a reservoir of *C. pecorum* ST23 infection for sheep is also possible but has not been thoroughly investigated.

1.6. Risk factors

While there is an increasing number of cases of *C. pecorum* abortion being reported across Australia and New Zealand, the majority are field investigations and comprehensive epidemiological data to assess risk factors for reproductive disease is limited. Nevertheless, it is likely that the outcome of *C. pecorum* infection is multifactorial and dependent on the pathogenicity of the strain involved as well as the immune status, pregnancy status and stage of pregnancy of the ewe, and infection dose. The predominance of cases involving maiden ewes (Table 1) suggests ewe age, and possibly immune status, may be an important risk factor for disease outcome.

Higher stocking densities may increase opportunities for transmission from ewes that are shedding the bacteria or exposure of ewes to aborted material containing C. *pecorum* ST23. However, abortions and perinatal lamb deaths because of *C. pecorum* have been observed in a range of enterprises, including extensively grazed flocks [15]. *Chlamydia psittaci* can survive in the environment for up to 30 days [24]. However, further investigation regarding the host cell-free survival of *C. pecorum* ST23 in the environment is required to understand the importance of environmental contamination in disease transmission.

A state of latent infection is described for the closely related *C. abortus* where ewes that are immunologically naïve but infected before pregnancy remain asymptomatic until the next pregnancy when reproductive disease may occur [25,26]. It is unclear if a similar pathogenesis occurs for *C. pecorum* ST23.

1.7. Diagnosis

Definitive diagnosis of *C. pecorum* involves bacterial isolation and/or nucleic acid amplification assays (e.g. PCR) alongside supportive histopathological lesions and immunohistochemistry. Culture of *C. pecorum* is laborious and prolonged, therefore, molecular diagnostic techniques such as qPCR are more regularly utilised by veterinary laboratories. Placenta is the preferred tissue specimen for detecting abortigenic agents, including *C. pecorum*. However, *C. pecorum* ST23 has also been detected in the kidney, liver, spleen, abomasal fluid, heart, lungs and brain of aborted and stillborn foetuses [14,16], so a full suite of foetal tissue samples should also be submitted where possible.

The use of dam serology (CFT) can demonstrate exposure to *C. pecorum*. However, serostatus has poor specificity for disease outcomes, being complicated by antibody response to “non-pathogenic” enteric strains. Vaginal swabs are useful to some extent, but depend on the availability of genotyping, to differentiate ST23 from “non-pathogenic” enteric strains, and other samples are required for exclusion of other common abortigenic pathogens (e.g. *Campylobacter, Listeria* and *Toxoplasma*).

1.8. Management options for outbreaks and prevention

Current recommendations for prevention and the management of outbreaks are relatively generic. These include reducing and avoiding stress in pregnant ewes and removing aborted material to avoid point source infection and contamination of feed and water sources. Identifying and separating ewes that have aborted can be challenging in extensively managed flocks. Risks associated with disturbing the rest of the flock in late pregnancy or during lambing probably outweighs the benefits of removing the ewe(s), especially given our knowledge that asymptomatic ewes can also be shedding *C. pecorum* ST23.

Anecdotally, it appears that ewes that have aborted due to *C. pecorum* rarely abort a second time, therefore, culling ewes that have aborted is unlikely to be beneficial.

Reactive antimicrobial therapy with long acting oxytetracycline in a New South Wales flock where abortion was detected prior to the start of lambing appeared to prevent further abortions. The use of oxytetracycline has also been described for abortion outbreaks associated with *C. abortus* [27]. However, there are no published case-control experimental studies to confirm success of antimicrobial treatments during abortion outbreaks.

Given the potential for carrier states, avoiding introduction of new ewes into a flock during mid- or late-pregnancy and keeping maiden ewes separate from older ewes in late pregnancy may reduce transmission to susceptible ewes and reduce the incidence of *C. pecorum* associated reproductive disease.

Currently, there is no vaccine against *C. pecorum* available for use in sheep. However, vaccine-based strategies to prevent disease have successfully been implemented for koalas [28] . Overseas, commercial live attenuated vaccines are available for C. *abortus* to reduce abortions (eg. Cevac Chlamydia ® (Ceva Animal Health Ltd) or Enzovax®(MSD)). Experimental *C. pecorum* vaccine trials using recombinant chlamydial protein antigens in pregnant ewes have demonstrated modest cellular and humoral immune response [29]. Continued exploration of the *C. pecorum* genome will inform improved design of a *C. pecorum* vaccine by identifying novel peptides. Whilst the potential for a vaccine to be developed is promising and may be beneficial in preventing several disease manifestations (abortions, arthritis, conjunctivitis), industry demand for a vaccine must first be established before funding is pursued. Consideration must also be given to potential implications *C. pecorum* vaccination may have for the serostatus of enterprises who export live animals or genetics.

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A strategic plan for the Australian goat industry and the role of private practitioners: a GICA perspective

J Falkenhagen
Goat Industry Council of Australia, Meningie SA

The Goat Industry Council of Australia (GICA) is the peak national body representing the interests of goat producers. GICA's objective and purpose is to represent and promote the national interests of Australian goatmeat, fibre and dairy producers.

GICA is designated as a Commodity Council of the Federation by Federal Government. Under its charter as a Commodity Council, GICA is specifically designated as the organisation that develops collective goat industry policy, across all breeds. GICA works with Government, industry bodies, producers, farmers and other peak industry councils to this end.

The Australian goat industry is continuing to grow and evolve to meet increasing global demand for goat meat, dairy products and fibre.

Several drivers have been successful in growing the consumption of other niche proteins such as turkey, kangaroo and duck and could be used to boost consumption of goatmeat in Australia.

Something special – encourage consumers to make a restaurant-quality goatmeat dish at home by providing them with the information and inspiration.

New food culture – drive a new trend by leveraging the fact that goat is consumed all over the world, increasing mealtime variety. In particular, increasing the popularity of cuisines that feature goatmeat including Southern Asian, Caribbean, Mexican and Middle Eastern.

Seasonal suitability – just as summer is the season for seafood and spring is for lamb, winter could be the popular season for goatmeat, as reflected in a number of Asian countries, when slow wet cooking methods are more popular.

Health credentials – goatmeat is lean and associated with health benefits in some Asian markets.

(Source: MLA/DIJ Strategy, Value Adding Goatmeat for Australian Consumers 2017).

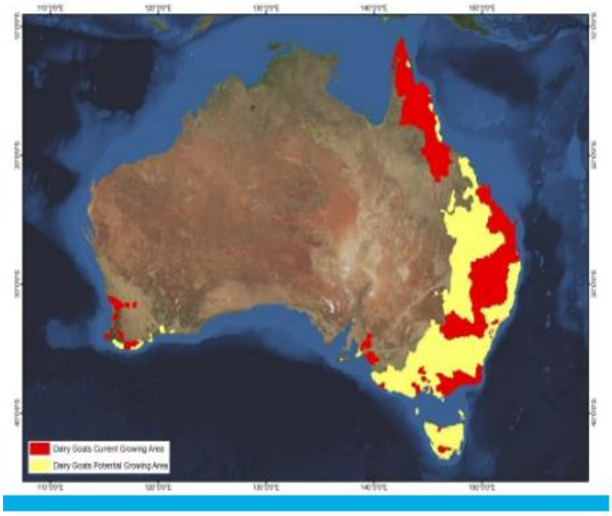
Goats arrived in Australia with the First Fleet in 1788 and spread with settlers throughout the country. The original goats were a varied and hardy herd capable of utilising harsh Australian pastures to produce milk and meat.

Some of the first herd escaped into the wild and have evolved into the unique Australian rangeland goat. These rangeland goats have since contributed to the development of the modern Australian Cashmere and Angora breeds which have been invaluable to many farmers as they diversify their income. These rangeland goats have become the mainstay of a growing goatmeat industry. Boer and Kalahari reds are goat breeds that have been more recently introduced into the Australian goat meat industry.

There are six recognised dairy goat breeds in Australia: Anglo Nubian, Sanann, British Alpine, Toggenburg, Australian Brown and Australian Melaan

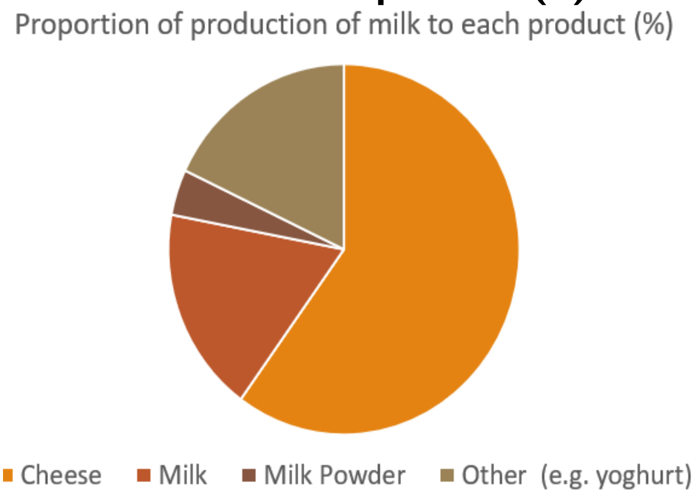
DAIRY Estimated farm-gate value of $20.2 -$20.69 million (2017)

Current and Potential Australian Dairy Goat Farms



Map of current and potential growing regions

Proportion of Production of milk to each product (%)



Sourced from AgriFutures Australia – 24/05/2017. The Australian Dairy Goat Industry. An assessment of the population and farm gate value, AgriFutures Australia 2017

Fresh milk is mainly supplied as a health product to people intolerant of cow's milk. It has also recently become more popular as a gourmet milk, as cheese, yoghurt, soap, moisturisers and in fine dining restaurants. 60% of milk produced goes to cheese production, 18% to fresh milk and the remainder to milk powder and other products

Typically dairy goat lactation lasts for 300 days with an average of 2-3 litres of milk per doe per day. At peak lactation this can increase to 3.5-4 litres per day.

Fibre

There are two fibre goat breeds in Australia – Angora goats (mohair) and Cashmere goats.

In 2009, world production of mohair was approx. 5000 tonnes a year, down from a high of 25000 tonnes in the 1990s. Australia is currently only a small player on the world scene, contributing less than 5% of the world total.

Australia currently produces around 10-12 tonne (including hair) cashmere per year. Global demand exceeds supply which presents opportunities for the industry to develop.

Meat

All breeds of goats and their crosses produce potentially saleable goatmeat.

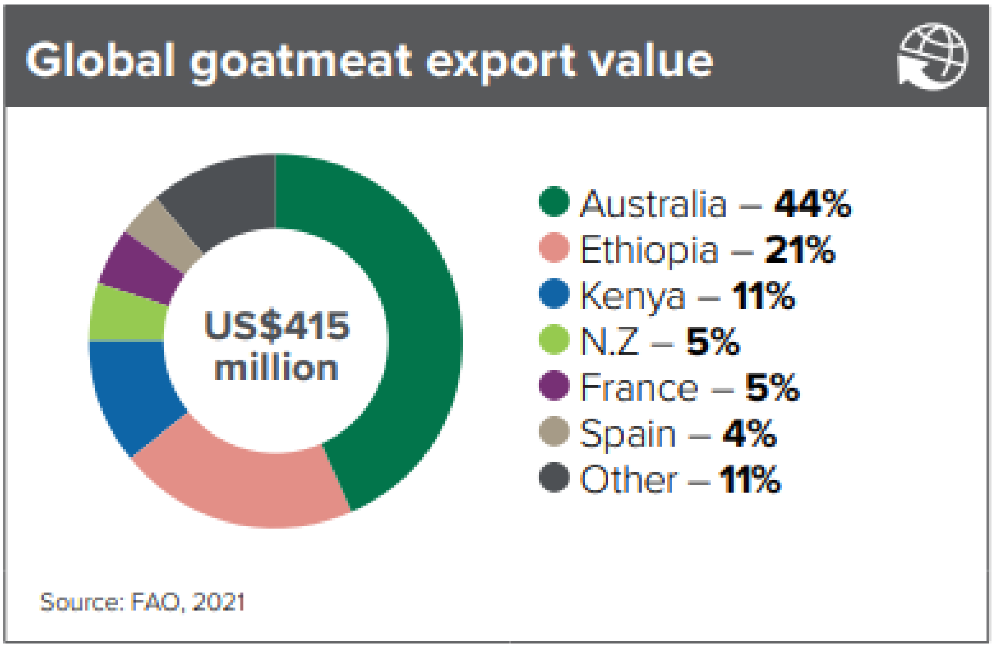
Goatmeat is the most widely consumed meat in the world, mainly due to the few, if any, religious taboos limiting goatmeat consumption.

The main breeds of goat that are used for meat production in Australia are the rangeland and Boer goats. Other meat goats include the Kalahari Red.

Australia is a relatively small producer of goatmeat but is the world's largest exporter of goatmeat.

Traditionally, Australian bush goats (rangeland goats) and Boer goats are used for meat production.

About 90% of goatmeat production is produced by rangeland goat enterprises.



Australian goat market summary

Goatmeat is a niche protein with relatively low consumer awareness and limited availability in Australia's major retail and foodservice

channels. Only about 9% of domestic production is consumed in Australia, with the rest exported.

Australian goat market summary

Calendar year	2021	2022	% change 2021–22
Slaughterings ('000 head)	1,210	1,671	+38.1
Average carcase weight (kg/head)	17.2	17.02	-1
Production ('000 tonnes carcase weight)	20.5	28.5	+36.6
Goatmeat exports ('000 tonnes swt)	19.0	21.8	+14.5
Goatmeat exports (A$ millions)	242.0	262.5	+8.5
Live goat exports ('000 head)	12.0	4.9	-60
Live goat exports (A$ millions)	5.0	3.8	-23

Sources: ABS, DAFF, IHS Markit

Source: Global Snapshot – Goatmeat MLA

Rangeland

The Rangeland goat is the major source of goats for the goatmeat processing industry, accounting for 90% of total goat meat production.

Rangeland goat traits include:

- Hardy and can thrive in low rainfall zones
- Maintain high fertility in dry conditions
- Suitable for commodity goatmeat trade and live trade
- Low maintenance – do not require shearing, crutching or mulesing
- Exhibit hybrid vigour when crossed with other breeds, for example Boer.

Priorities, projects and policies

As the peak national body representing the interests of all goat producers, GICA oversees a number of projects and policies which help to secure the long term sustainability and profitability of the industry.

These include:

Animal health and welfare

- Animal health and welfare is vital in any livestock industry and GICA is committed to ensuring it is upheld throughout the entire goat industry supply chain. GICA oversees the investment of industry levies with the specific mandate of developing cost-effective, practical solutions to animal health and welfare concerns within the goat industry.

Research and development

- GICA regularly assesses areas within the goat industry that could benefit from targeted research and development programs. A number of these are ongoing initiatives, while others work towards an end goal.

Trade and marketing

- GICA works to ensure that markets for goats and goat products remain open and sustainable, while overseeing marketing initiatives aimed at increasing the consumption of Australian goatmeat and other goat products domestically and internationally.

Biosecurity

- GICA works closely with Animal Health Australia, (AHA) to administer animal health programs and ensure emergency animal disease preparedness for goat producers in case of a disease threat. In association with other industry bodies this has resulted in biosecurity guidelines and the farm biosecurity programs.

Livestock exports

- Australia is globally recognised as a supplier of high quality live goats. All goats are exported from Australia according to world’s best practice. The vast majority of live goats are exported to Malaysia.

GICA FY2024 priorities

- Pain relief project

- Anthelmintics project
- HRG Accreditation framework operational
    - New NVDs
    - Goat Depot and HRG Manuals
    - NLIS and LPA updates
- Goat industry communication and extension program
- Goat welfare Standards and Guidelines Review
- Goat industry levy review
- Animal Health Statement update
- Industry sustainability framework

Working together to deliver the strategy

Vet:Producer relationship presents a lot of opportunities beyond response

- Practical solutions on-farm including off-label use of pain relief and anthelmintics
- Health and welfare advice linked to commercial production
- On-call support and treatment
- EAD preparedness and response
- Engaging with small producer groups
- Annual farm visits for production animals (S4 use)
- Reproduction and genetics
- Working with other advisors (agronomists) to increase overall commercial productivity

Useful resources and more information

- Meat and Livestock Australia (MLA) Goat Hub
- Animal Health Australia (AHA)
- Goat Industry Council of Australia (GICA)
- AgriFutures
- Goat Diseases Guide: The farmer's guide
- State departments of Agriculture/Primary Industries
- State Farming Organisations
- Farming Groups and Breed Societies

Injectable trace minerals associated with a vaccination program against *Haemonchus contortus* increase ADG and reduce WEC in lambs: a pilot study

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Introduction

Gastrointestinal nematodes cost the Australian sheep industry $369 million annually, or 8.7% of its total value [1]. Barber's pole worm (*Haemonchus contortus*), a blood-feeding nematode that parasitises the abomasum, is one of Australia's most important sheep roundworms. Barber's pole worm infestation alters haematological, biochemical, trace mineral and oxidative stress markers in sheep. It significantly reduces serum immunoglobulin (IgG and IgM), limiting its release into the abomasum and reducing protection against the parasite [2]. It is accepted that immunity to the parasite is achieved not earlier than 18-24 months of age in sheep, and lambs under six months of age cannot mount an effective immune response to *H. contortus* due to a delay in developing acquired immunity to the parasite [2,3].

Several strategies have been evaluated to improve the host's resistance to gastrointestinal parasites. Vaccination and trace mineral nutrition are some of them. Vaccination against barber's pole worm can effectively prevent and reduce parasite burdens in lambs. Like all vaccines, it stimulates an immune response. The antibodies circulate in the blood, and the parasites ingest them with their blood meal. The antibodies then attach to the intestinal lining of the worms, blocking digestion and starving the worms so that they produce far fewer eggs and die [4].

Trace minerals Cu, Se, Zn, and Mn are necessary for immunity and antioxidant enzyme activity. Copper, Mn and Zn are structural and functional components of the antioxidant enzyme superoxide dismutase (SOD), and Se is a component of the enzyme glutathione peroxidase (GPx). These enzymes protect leukocytes against free radical damage. Trace minerals play essential immune functions in epithelial integrity, leukocyte migration, phagocytosis and killing of bacteria, cytokine production, antibody production and cell-mediated immunity [5]. The mechanism of how trace mineral supplementation results in reduced parasite burden and increased resistance is unclear, raising the question of whether it directly affects the host gastrointestinal tract or the immune system.

Serum Zn and Cu concentrations have been found to be significantly lower in barber's pole worm-infested sheep, associated with reduced antioxidant enzyme activity (e.g., SOD) and high peroxidative markers (e.g., malondialdehyde). Reduced trace mineral concentrations in the blood can result from extensive utilisation to support the immune response or reduced absorption secondary to low feed intake and changes in rumen pH and gastrointestinal integrity due to parasite infestation [2]. On the other hand, Zn supplementation has resulted in reduced parasitic infestations, and Mn supplementation has had a significant negative correlation with WEC in sheep. Copper oxide wire particles can reduce abomasal nematode populations in sheep by 56–96% but have no effect on the establishment of intestinal populations. Additionally, under experimental conditions, dietary Mo can reduce the establishment of abomasal and intestinal nematodes but not their pathogenicity to lambs [6-9].

Injectable trace minerals (ITM) containing Cu, Se, Zn and Mn allow the delivery of specific amounts of trace minerals, by-pass antagonist interactions within the gastrointestinal tract and overcome variability associated with fluctuations in voluntary intake of free-choice mineral mixes. ITM can complement oral supplementation, help improve trace mineral status and support challenging events of the productive cycle (weaning, joining, pregnancy, transport) by enhancing antioxidants, immunity, and fertility [5, 10, 11].

Studies have demonstrated that ITM can improve vaccination responses against viral and bacterial diseases in cattle [12-16] and are effective in increasing and/or lessening decreases of trace mineral serum concentrations after vaccination in beef calves [12]. Furthermore, ITM can shorten the time needed to reach protective antibody production by increasing serum neutralising titres, resulting in more animals that seroconverted on day 28 after vaccination [14]. ITM may enhance the humoral immune response by mechanisms additional to or complementary to increased trace mineral status. This suggests that adding ITM to livestock management protocols might represent a promising tool to improve health on commercial livestock farms [17].

However, the effects of ITM associated with a vaccine against parasites in sheep have not been investigated. This study hypothesised that ITM associated with an *H. contortus* vaccination in lambs could reduce *H. contortus* worm egg counts (WEC) beyond that which is expected with the vaccine alone.

Material and methods

Sixty lambs were allocated to two treatment groups based on body weight at marking (day 1 of study). All lambs received Barbervax® (Wormvax Australia Pty Ltd) according to published protocols [16]. From weaning (day 45 of study), 30 out of 60 lambs received an ITM product containing Zn, Mn and Se (Multimin® Copper-free Injection for Sheep and Cattle, Virbac Australia Pty Ltd) twice three months apart (i.e., days 45 and 136). An ITM without Cu was used in this trial based on farm history and management, blood tests from pregnant ewes and pasture samples that showed a high Cu: Mo-S and normal high concentrations of Cu in plasma.

All lambs were drenched (derquantel and abamectin) at weaning to control scour worms and early-stage barber's pole worms. They were injected with 6-in-1 clostridial and cheesy gland vaccine plus vitamin B_{12} (Websters® 6 In 1 Vaccine B12, Virbac Australia Pty Ltd) at marking, and given a booster at weaning. All lambs were moved to a prepared low worm-risk paddock, where sheep had not grazed for three months. Lambs were weighed every 14 days, and faecal samples were collected every 14 days from weaning for individual WEC and larval differentiation (Figure 1).

Bodyweight (BW) data were analysed using ANOVA in GenStat. *H. contortus* WEC data were analysed using the Chi-square test in MedCalc. Significance was defined as $P < 0.05$. The efficacy of the treatment was calculated as follows:

Mean EPG (eggs per gram) of control – Mean EPG of treatment / Mean EPG of control x 100

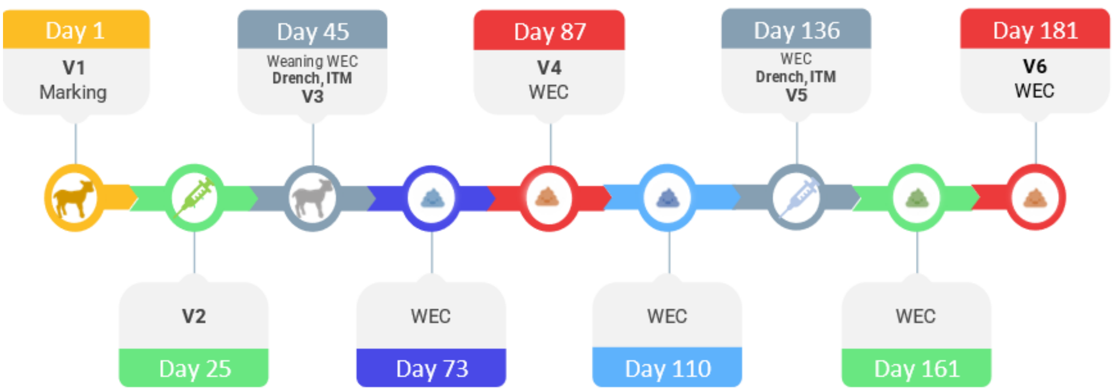

Figure 1: Trial timeline (V1-6: Barbervax® injections; WEC: individual worm egg counts; ITM: injectable trace mineral Multimin® Copper-free Injection for Sheep and Cattle).

The weaning drench administered on day 45 was expected to bring WEC to zero. However, high WEC on day 75, consisting primarily of barber's pole and black scour worm eggs, necessitated a salvage drench (levamisole, albendazole, moxidectin, monepantel and abamectin) on an animal welfare basis. Additionally, all lambs were drenched with derquantel, abamectin and naphthalophos on day 136 due to high WEC.

Results and conclusion

This pilot study demonstrated that the use of ITM at weaning (day 45) and 3 months later (day 136), in conjunction with 6 doses of Barbervax® vaccine, resulted in a significant reduction of *H. contortus* eggs and higher treatment efficacy (between 41 to 85 %) on days 73, 110, and 136 ($P < 0.05$) compared to control animals (Table 1, Figure 2).

Table 1: Worm egg counts (WEC) and larval culture percentages by treatment, and percent efficacy of injectable trace mineral treatment (ITM: Multimin® Copper-free Injection for Sheep and Cattle) on barber's pole worm WEC for 4.5 months after weaning.

	Day 45 (Weaning V3)		Day 73		Day 110		Day 136 (V5)		Day 161		Day 181 (V6)	
	ITM	Control	ITM	Control	ITM	Control	ITM	Control	ITM	Control	ITM	Control
WEC, epg (sd)	1082 (1173)	1148 (1039)	876 (994)	1419 (2376)	510 (961)	469 (538)	1137 (846)	1254 (851)	91 (161)	56 (89)	1202 (681)	1172 (964)
H. contortus, %	86	86	77*	81	7**	17	4**	25	48*	29	9	11
Efficacy, %	6		41		55		85		-116		16	
Trichostrongylus, %	12	12	18	15	89	70	82	57	49	47	75	83

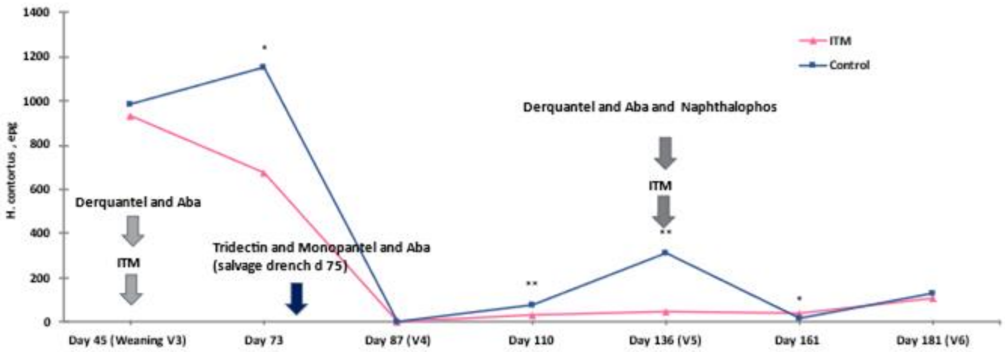

Figure 2: Change in *H. contortus* egg count (epg) by treatment during the trial (ITM: Multimin® Copper-free Injection for Sheep and Cattle; ** $P < 0.001$ * $P < 0.05$).

Lambs treated with ITM on days 45 and 136 gained significantly more weight (+1.72 kg; $P < 0.05$) and had a higher ADG at 181 days (128 vs 141 g/day; $P < 0.05$; Figure 3). Drench resistance may have hindered weight gain, but more data needed to be gathered to identify this.

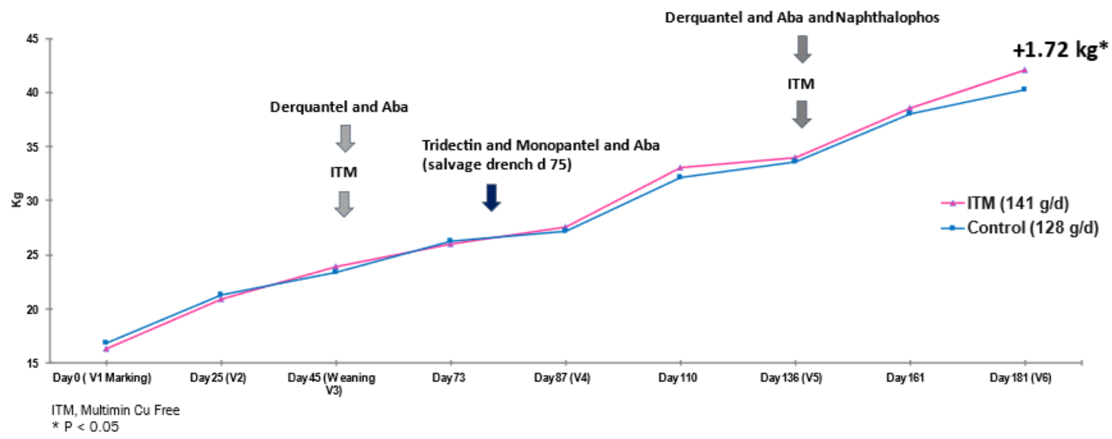

Figure 3: Change in body weight (kg) and average daily gain (g/d) by treatment during the trial (ITM: Multimin® Copper-free Injection for Sheep and Cattle; * $P < 0.05$).

This study demonstrated that using ITM (Multimin® Copper-free Injection for Sheep and Cattle) at weaning and three months later, in conjunction with 6 doses of Barbervax® vaccine and regular WEC and larval cultures to monitor (and treat as necessary) worm burdens, resulted in a significant reduction of *H. contortus* worm egg output on days 73, 110, and 136 and higher BW and ADG at 181 days (4.5 months post-weaning) compared to control animals. It is suggested that ITM may increase the immune response to barber's pole vaccination. Further studies can help to understand the mechanism behind our results, i.e., antibody responses, change in antioxidant status, trace mineral levels, and specific markers for *H. contortus*.

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Animal Health & Nutrition Consulting: a start-up story

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It's hard to leave a secure, comfortable job as a government veterinarian. I loved this job for many years, but reflecting on leaving twelve months afterwards, it's very true that all good things come to an end! I am deeply thankful for the catalysts that prompted the move into running my own business.

I was probably always better suited to the commercial world. I wanted to strive, achieve, diversify and try new things. I wanted to run a good show. I'd had clients urging me to go private for years. I had built a considerable amount of equity in what I was doing that I couldn't capitalise on within the parameters of the salaried job I was working. I don't mean financial equity, I mean personal and professional equity, reputation, skills and brand development.

But for a long time, I was terrified. I couldn't be what I couldn't see. And I couldn't see many (any!) mid-stage female career professionals breaking out into their own businesses. I came from a financially conservative family, and well-paying jobs in small country towns are hard to come by. "Don't leave your job" was the advice from my parents, my bank manager and some of my farmers. One farmer came to my farewell, put her arm around me and said "I think you're mad and you're going to go broke". I've thought of that every day since.

What I could see around me were traditional veterinary practices – reactive veterinary practices who dealt with mixed caseloads, after hours call outs, and the growing difficulty of attracting and retaining graduates. I love the private vets in our area and regard them as some of my closest friends, but time spent in a clinic treating small animals and servicing livestock callouts did not stoke my fire, and it did not suit my skillset. The chat on the Australian Sheep Vets email list about the dire future of rural private practice also filled me with dread.

I could see men a generation older than me that were running livestock focused businesses but they were all located far away from me, in more intensive livestock areas, and most of them had hinged their consultancy work on a base of sheep scanning, artificial insemination or feedlot work. They also had many more years of experience and potentially more support to kickstart themselves.

Was it possible to be a livestock consultant to extensive sheep and cattle producers across north west NSW, get enough clients and earn enough money to stay afloat? I was about to find out.

I had a clear idea of what sort of business I was trying to run

The idea for AHN had been percolating for quite a while. I believed that most livestock animal health issues are caused by lapses in husbandry, management or nutrition. I believed strongly that if we could offset these problems before they occurred, we could reduce deaths, improve weight gains and that the benefits the producers reaped would pay for my services. I had a track record of doing this in my previous roles, however the advice often came after the "disease investigation", not before.

I wanted to offer proactive livestock production services. I deliberately didn't start preg-testing cows or scanning sheep because I wanted my business to be focused around advisory work – the transfer of useful, practical, evidence based timely information. While providing technical services might generate income, I knew that it would damage the focus of the business and I also wanted to maintain a good relationship with the private practices across the areas that I was working – I didn't want to steal their core business.

I knew in my mind what sort of business I was trying to create. I finished my salaried job on the 29th of July 2022. I started Animal Health & Nutrition Consulting on the 1st of August 2022. I peddled as hard as I could, and it wasn't until January 2023 that I sat down and wrote a business plan, which really helped solidify what I was doing and where I was going.

I taught myself to run a business before I started

I started painting with watercolours in 2016 and sold a few pieces, under the brand, Miss Vet. The business grew and it expanded into greeting cards and prints. I did a social media course, started an Instagram account, built a website, did a few markets, sold a few items through the local gift store. Then, at the depths of the drought, my friend Grace Brennan started Buy from the Bush and I got involved in the movement. Things really took off and sales increased. I was selling about 5000 greeting cards a year and doing around 100 commissions. My hobby had become a business and I had to run it like one. I got a good accountant.

In 2017 I bought a hobby farm, got set up as a primary producer and started trading cattle. It was a small amount of land, but after learning a valuable lesson and losing money on the first mob of steers I traded, I worked out how to trade. I got a good agent, would do a feed budget, study the markets and make short, sharp trades on whatever class of animal that suited the feed available for a profit. I was able to claim plenty of expenses against this enterprise, which was a tax advantage.

I did a Small Business Accounting course at TAFE, which I failed (but I learned a lot). I started using Quickbooks accounting software. I did a Business Activity Statement every quarter. I looked at the profit and loss statements and talked to the accountant regularly.

The day that I decided to start AHN, I wrote a resignation letter, drew a logo and called the accountant and asked her to set up whatever sort of a business structure would suit a veterinary consulting business. Turns out, that business structure is a proprietary limited company, and I had most of the skills and contacts necessary to start it.

AHN was a low input, low overhead start-up

Hopeful, but unsure if it was going to work, I put $5000 into the business to start up. I spend $2000 of this on trucker caps as promotional items (my accountant shook her head). The rest, I spent on a toolbox on the Hilux that I already owned, a bit of basic vet gear and supplies, some embroidered work shirts, an ad in the local paper and a website that I built myself. If I did go broke, at least it was not going to be spectacular.

I put a financial floor in the business

I felt strongly that vets give too much away for free - especially their knowledge. People close to me had often said that farmers loved the service they were receiving as part of a free government offering, but there was no way they would pay for it. I was determined that if people wanted the premium service that I was delivering under the AHN banner, they needed to pay for it.

I encouraged people to sign up yearly at a low price point – “Store Membership” ($99 for fortnightly newsletters), “Fat Membership” $249 for fortnightly newsletters and the ability to call with short questions throughout the year. By signing up, they were part of “Team AHN”, and they were bonded in some way to the business. I knew that $249 was undervaluing the time some of these subscribers would demand of me, however I felt that these were the sorts of conversations vets typically had to have to get on farm, and at the moment most of them were having them for free. I also felt that it was a more palatable alternative to having the conversation and then sending an invoice for my time.

My aim was to have 100 Fat Members which would put around $25,000 into the business without having to set foot out of the house or invest any money except my time. I achieved this in the first few months.

I also started my business in the midst of a wet spring, so offered Worm Egg Counts which put around $10,000 into the business in the first six months.

I gathered clients

I had around 20 clients sign up for on-farm consultancy packages in the first few months of business. Most of these were clients who were used to depending on my services and who wanted to continue the relationship. A few were complete strangers who had heard about the business through word of mouth, seen me at a workshop or field day, saw it on Facebook or always been interested in what I was doing but couldn't previously access my services due to previous geographical boundaries.

Twenty to thirty clients in the first twelve months was a goal I'd set in my head at the beginning and I'm lucky to have had this happen so quickly. I gave most of these clients an option of how to pay, and most chose to pay up front. This gave me a bit of working capital in the initial months of the business to get things started. I now choose to invoice clients quarterly for my services as it spreads the cash flow out across the year.

I found the Australian Sheep Veterinarians webinars on Sheep Business Models presented by Andrew Whale and Greg Johnsson to be inspiring. In particular, I learned a lot from Andrew's advice on pricing and the hourly rate that is required to cover costs and pay yourself and I have thoroughly taken this onboard.

I still do some fire-engine work to dead or sick stock. My ability to service these farmers is limited due to scheduled, packaged consulting work; however, I make an effort where I can as most of the fire-engine call-outs lead to them becoming clients and proactive service delivery in the future!

I upskilled in areas aside from veterinary science

A tiny portion of what I do every day is pure veterinary science. The rest is livestock nutrition, management and husbandry, financials and client relationships – things that as vets we aren't traditionally that skilled in!

I had an existing good relationship with Jill Rigney and the late David Hanlon from The Right Mind who have helped me immensely with personal and professional growth and leadership skills.

I completed the first round of Meat and Livestock Australia's Livestock Advisor Essentials program which focussed on pasture management, agribusiness accounting, livestock markets and supply chains and personal and professional growth. An outcome of the program was being paired up with a mentor. I got paired with John Francis from Agrista Agribusiness Consultants in Wagga, and our mentoring relationship has continued long past the course completion date! He has been an excellent teacher, mentor and sounding board throughout this whole exciting adventure, and our businesses are now working together to service our clients in a more rounded way.

In the first six months after starting AHN I did an RCS Grazing Clinic and a KLR marketing course. I did this because I wanted to be on the same page as my clients who are practicing these principles, and I ended up finding that I picked up little bits of knowledge from each of these courses and have incorporated them into the service I am delivering.

I became a mentor under the Australian Rural Leadership Foundation's Drought Resilience Program, learned a lot about mentoring and have remained in contact with my mentees.

I was curious, looked for opportunities and collaborated

This attitude led to the business being involved in research and extension projects, formation of Lifetime Ewe Management Groups, production benchmarking groups, speaking at workshops, field days and conferences, running educational events on topics such as sheep droughtlotting and using Excel to sort your sheep EID data and a four-year funded research project with MLA & Pinion Advisory. There are also lots of other projects in the pipeline!

The Challenges

To be honest, there is not much that I would have changed about the first twelve months of business and I think I'm incredibly fortunate that it has gone so well. I earned more than I made in my previous salaried role, which was a real achievement. There are probably a couple of clients that I wouldn't have taken on, in hindsight. I think it's important that the clients that I work with are capable of change and growth and I now try to assess this before I say yes!

One challenge of the business that I've set up is that the income generation is largely dependent on how many billable hours that I've got in a day/week/year which is capacity limiting. The other challenge is that the current success of the business is that it is largely built around my contacts and reputation. How I onboard new staff into the business and maintain this is something that I need to handle carefully.

What's Next?

I plan to strengthen AHN by building a team of people who strive to make the business a leading provider of trusted information and a promoter of excellence. I plan to continue to provide a high standard of quality service to the existing client base and evolve ways to bring the service to more producers. I plan to prove that farmer from my farewell wrong – and not "go broke"!

The Danger Zone: inducting sheep onto grain

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Introduction

Drought lots and opportunistic on-farm feedlots are becoming more common in sheep enterprises across Australia. The first few weeks of grain feeding can be when the highest levels of nutritional care, monitoring and management are required. It is also when the most mortalities occur and the veterinarian is called out to assist. This paper aims to introduce clinical mixed practice veterinarians to good induction protocols and common induction methods used in sheep. It will discuss the principles behind ration development and delivery, how a rumen adapts to grain, induction methods and timeframes and technological options for feed delivery.

Rumen Adaption

When sheep transition from grazing a fibrous diet to grain, the rumen undergoes microbial, chemical and structural changes.

Microbial populations gradually shift in type and number after each major feed change. Forage fibre digesting microbes take 3-4 weeks to fully adapt, and these microbes double in number every 18-24 hours. Starch and sugar digesting microbes take around 4-5 days to adapt and reproduce quickly, doubling every 2-3 hours.[1]

The ruminal microflora of sheep grazing a fibrous diet contain more anaerobic fungi, as these act on the fibre stalk first, breaking down the tensile strength of the feed, solubilising lignin and breaking down the hemi-cellulose and lignin complexes. Bacteria can then attach to further the digestion process. Protozoa then feed on bacteria, sugars and starches, so there are commonly less of these in a high fibre diet, compared to a cereal grain diet. The rumen pH of a pasture or hay diet is commonly between 6 and 7. The volatile fatty acid profile produced by a high fibre diet leans it more towards the production of acetate and butyrate rather than propionate. Rumination, or cud chewing, is common on a high fibre diet and is an important part of healthy rumen function as it causes salivation. Saliva provides important rumen buffers such as sodium bicarbonate and disodium phosphate to the rumen to help neutralise the pH and recycle minerals. Fermentable fibre is a very important energy source for rumen microbes[2].

The ruminal microflora of sheep on a cereal grain diet contain more bacteria and protozoa, which are amylolytic (starch digesters) and less anaerobic fungi than those on a high fibre diet. The rumen pH on a grain diet is typically between 5.5-6.5. Because these types of feeds contain high levels of starch and have high fermentation rates, the overall concentration of volatile fatty acids increases and the profile is skewed towards propionate, rather than acetate and butyrate. Propionate drives high levels of blood glucose which is important for the survival of lambing ewes and also for weight gains in production feedlots. As the grains are highly fermentable and small, there is little reason for rumination or cud chewing, and as a result the production and swallowing of saliva is reduced[2]. Furthermore, the rumen epithelium will increase its tissue mass in a variety of ways to increase the absorptive capacity – for example it will change the degree of proliferation of the fraction of basal cells, change the cell division rates and adjust cell transit times – grossly we see the rumen papillae grow in number, length and width[3].
With increased volumes of cereal grain, the ruminal pH reduces as a consequence of the increase in the volatile fatty acid concentration and the reduction in saliva production. As a result, the number of acid-tolerant bacteria rises. If the pH drops below 5.5, signs of sub clinical

acidosis occur. Furthermore, some of these bacteria start to produce lactate, which is not as useful to the animal and it rapidly lowers the ruminal pH to below 5. Lactic acid is ten times as strong an acid as propionate and so once it is produced, the descent into clinical acidosis is rapid[2].

Excessive grain diets without adequate effective fibre (that will scratch and clean the ruminal wall) can lead to ruminal parakeratosis, although it is noted that this condition is less likely in animals fed whole (rather than processed) cereal grains. A maladapted rumen that is acidotic also causes sloughing of the stratum corneum (top layer) of the papilla and gaps between cells, leading to a "leaky" rumen. The healthy rumen epithelium acts as a protective layer between the rumen environment and portal circulation - when it is compromised bacteraemia ensues[3].

The key to adaption of the rumen to cereal grain is to do it slowly and consistently enough that the ruminal microbes change in their population in order to digest the starches and sugars, that there are enough bacteria to utilise the microbial end products and that the ruminal wall changes in its structure and papillae size, number and health that the end products of ruminal digestion can be adequately absorbed.

The Induction Process

Preparation

Animals should be vaccinated for clostridial diseases prior to being inducted. 'Backgrounding', which includes getting sheep used to being grouped together and exposed to self-feeders, troughing and lick supplements in a paddock situation can help to speed up the induction process, improve feed intake, reduce health issues and reduce and shy feeders[4].

A general policy of imprinting lambs to eat grain prior to weaning (even in good years) will eliminate the time-consuming task of trying to teach animals to eat later in life. Imprinting involves feeding grain for 3-4 days prior to weaning, and that the feeds only need to be small – 100-150g/head/day.[5] It is best to expose animals for at least 3 to 4 days - research shows that exposures longer than 8 days provide no additional benefit as far as encouraging young animals to eat new foods.[6] The type of grain does not matter – familiarising animals with any grain will increase the likelihood they will eat another grain.[7] The process of imprinting overcomes neophobia and teaches the animal to put novel feedstuffs in their mouths.

Feeding Systems

Despite there being a number of automated feeding systems on the market, the author is yet to find one that safely and effectively inducts sheep onto cereal grain. Issues include:

- animals becoming accustomed to the feed automation process e.g.: hearing the mechanics of the feed delivery tube start up and rushing to the front of the tubing and eating more than their allocated share of the induction ration.
- not enough trough space for each animal to access the induction ration fairly, meaning that the shyer feeders won't compete.
- the producer thinking that the automation means that they can spend very little time with the stock, meaning subclinical disease issues aren't recognised until they are pronounced and clinical.

Similarly, the author finds it impossible to induct sheep onto grain using self-feeder systems because:

- animals can generally eat more than the quantity set on the feeder.
- there is not enough trough space for an induction process so that every animal gets equal access to a small volume of grain initially.

While it is understandable that producers are looking for time and labour-saving innovations, it is imperative that the cereal grain induction process is undertaken with adequate care and attention, which ultimately involves their commitment in the form of trough or trail feeding each day for the first 10-14 days.

Shy Feeders
On average, up to 5% of sheep that are inducted onto cereal grain are "shy feeders" and won't adjust to the grain feeding diet, even if imprinted[4]. Shy feeders can be identified as those that do not come onto the trail or trough, those that look "hollow" or "tucked up" or those that are identified on weighing as lighter. Alternatively, blue food dye is marketed by Advantage Feeders for inclusion onto grain during the induction period – animals with blue mouths have been eating the grain, those without the colour are shy feeders. It is worth noting that this dye only identifies the sheep that have eaten no grain, not the sheep who have had a nibble on occasional days and walked away. There is still no substitute for close observation and stockmanship when it comes to identifying shy feeders during the induction period. Shy feeders are best placed back onto pasture or a hay diet, or sold.

If the animals have not been imprinted while still suckling from their mothers, the shy feeder rate will be higher – around 10-15%[4] and great perseverance will be needed during the induction period to encourage these animals to eat.

Space
During the induction period, all of the animals must be able to get equal access to the feed. This means that if there is single sided access to the troughing or trail, 30cm per animal is required. If there is double sided access, 15cm per animal is required.[4]

Adequate pen space is also required. At least 5m^2 per sheep is a guideline, and mob sizes of <350 sheep get the best results when production feeding. If inducting adult sheep for maintenance feeding, larger mobs are acceptable.[4]

Sheep should be drafted into similar body weights and the shy feeders or poor doers removed regularly. This often involves redrafting every 2-3 weeks initially.

Diet & Feed Allocation
If the animals are going to be fed a Total Mixed Ration with grain and roughage combined, the induction diet can include more roughage and less cereal grain, for example 10% grain, 90% hay, slowly increasing the percentage of grain by 10% every 1-2 days over 10-14 days until the final ration is reached.

If the animals are going to be fed in a more typical grain and hay separate feeding system, giving the animals ad lib access to hay and feeding the grain in a trail or a trough is advised. The grain ration can start at 100g per head per day, building up the ration up by 10% every 1-2 days over 10-14 days until the final grain allocation is reached[8]. The transition process can be quicker if the animals are fed 2-3 times per day, rather than once.

Trailed grain and TMRs are best fed in troughing or even on conveyor belt to minimise faeco-oral transmission. The amount of grain over the first few days will be quite small – so care needs to be taken to run the ration out in a long enough trail to allow all sheep to have access.

If required, the ration can be transitioned to every second day (as is common in maintenance feeding regimes) after day 14[8]. If the plan is to transition the sheep onto self-feeders, it is best if the transition period occurs while the sheep have access to the closed self-feeders, and around day 10 of the process the self-feeders are opened gradually. Remember it is difficult to use self-feeders in a maintenance ration as almost universally the sheep can eat more than the desired amount. As such, they are usually used in production feeding. One 2.4m self-feeder per 100 sheep, or 3-5cm per head is recommended[4]. Often, and puzzlingly so, insufficient trough space causes a mix of overeaters and shy feeders in the same mob.

There is no need to process cereal grains, however if the ration includes a cereal and a pulse grain combined, processing (cracking or rolling) the pulse grain so that the particle sizes of the grains are matched will significantly reduce the animals' ability to sort the grain.

If the diet is changed during the feeding period, for example there is a transition from barley to wheat, or a different batch of cereal grain is introduced, this should also be slowly introduced to the sheep using a "shandying" of the two grains, rather than just a direct switch. This will minimise any feed aversion or acidosis events.

With all induction protocols, the animals must still get their daily nutrient requirements. For example, if the stock require 9MJ of Metabolisable Energy per day and a ration that is 12% Crude Protein, then they cannot be fed a diet that does not meet these requirements (e.g. straw and a trickle of cereal grain) for the first few days of induction. This will cause weight loss and increase the incidence of disease. For this reason, ad lib good quality hay is preferable during the induction period.

The diet also must be balanced in terms of minerals, this can be done by adding 1% lime and 0.5% salt to the ration. Alternatively, supplying mineral licks ad-lib in tubs can help supply these ingredients without rusting the feed-out equipment and does help to relieve boredom during the feeding period.

If sheep show symptoms of grain poisoning during the induction period, return to the next lowest level of feeding for 2-3 days and treat individual animals for grain poisoning. Adding 2% bentonite, 1% sodium bicarbonate or a commercial buffer pellet to the grain at 3-5% can also help to reduce the incidence of acidosis.

Induction is best done when the weather is stable as fluctuations in barometric pressure or extremes of temperature can cause animals to become inappetant for a period of days, then rebound back onto the ration, upsetting the induction process and causing acidosis.

The author does not believe that a 100% grain ration is safe or suitable as a diet regardless of the additives or buffers added, despite it being favoured by livestock feeding companies and some producers. For the welfare of the sheep, rumen health and risk management, at least 10-15% roughage should be in the diet at all times.

Conclusion

The induction period is a vital time in the feeding regime of sheep. If it is done well, it will set the sheep up for high production and minimal animal health issues. If it is done poorly, it will often be the catalyst for a variety of morbidity and mortality events that occur during and soon after the induction period. Shy feeders and acidosis are very common and often occur concurrently, or underly other disease processes, confusing the diagnosis. Hopefully a better understanding of the induction period can make diagnosis, prevention and advice provision more effective.

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The ParaBoss Worm Egg Count Quality Assurance Program

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Introduction

The ParaBoss Worm Egg Count Quality Assurance (WEC QA) Program identifies Australian worm egg count (WEC) providers that deliver accurate and precise results and offers participants the means to benchmark their performance and improve if required.

Accurate and precise WECs allow sheep, goat, camelid, horse and cattle producers and their veterinarians or animal health advisors to correctly:

- Diagnose illness.
- Optimise drench timing to minimise lost productivity, animal welfare impacts, and drenching costs.
- Rank stock measured for resistance to worms.
- Assess the effectiveness of drenches.
- Assess the effectiveness of worm management strategies.

Method

Each winter participants prepare and conduct worm egg counts on a standard set of sheep faecal samples containing strongyle-type nematode eggs (predominantly *Haemonchus*) and submit their data. Data is analysed and reported by the University of New England, with businesses meeting the program criteria being certified by ParaBoss.

- Each business receives the same replicated set of zero-, low-, and high-WEC faecal sample subsets sent at the same time.
- Multiple operators at each business can participate and businesses should use their own preparation and counting process.
- Testing can occur within three weeks of dispatch (although longer is being investigated).
- Participants register, pay, and create a secure online WEC QA account where they enter their results, view their report, and download other resources.
- The data is analysed:
  - The accepted mean egg count for the high- and low-WEC sample sets are determined using a consensus mean calculated from the results of 10–20 proven individual operators participating in the program that year. A Poisson distribution analysis establishes the 95% and 99.73% confidence intervals either side of the mean. Means within the 95% confidence interval are considered to have met the program criteria, between the 95% and 99.73% confidence intervals have minor issues, and outside the 99.73% confidence interval have major issues.
  - The variance ratio (measuring precision or variability of counts) is calculated with this formula:
    SQRT ((VAR(of the 5 samples)/Multiplication Factor^2)/(mean of 5 samples/Multiplication Factor)).
    Variance ratios below 1.5 meet the criteria, above 2.0 have major issues, and those in between have minor issues.
  - The mean WEC is plotted against the variance ratio for each operator, separately for their low- and high-WEC sample sets. See Figure 1.
- The position of each operator on the low- and high-WEC sample set graphs is classed as “having met the standards of the program”; “having minor issues”; or “having major issues”, with these results presented in a table.
- Certification is for a business rather than individuals and is based on criteria that takes account of the proportion of the classes of results across the business’s operators (results from trainees are excluded from assessing the business).

- An online report is provided with (a) the graphs (the positions of each operator within one business are identified against a background of the positions of unidentified operators from the other businesses, (b) the table of classed results, (c) whether the business is certified, not certified, or provisional (has the opportunity to become certified if they satisfactorily demonstrate how they will resolve minor issues), and (d) additional notes.
- ParaBoss Certified WEC providers (that provide permission) are published on the “Find an advisor page” on the ParaBoss website and as a group are promoted via ParaBoss communication channels.
- Certified businesses can use a ParaBoss Certified WEC Provider logo until the next round of the program is completed (one year).

High epg samples

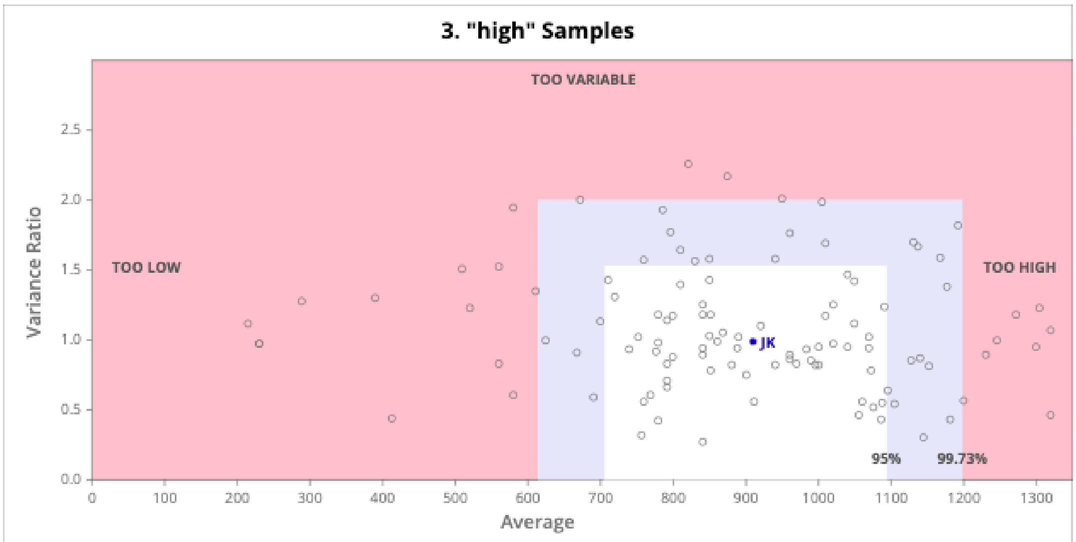

Figure 1. Results for the High set of samples from all operators in the 2022 program.
Samples number 2, 3, 5, 8, and 11 contained the high level of worm eggs.

Discussion

The ParaBoss WEC QA Program has operated in 2019, 2021 and 2022 each time with approximately 130 operators and 45 businesses. About 60–70% of businesses are certified immediately, 20–30% are certified after fulfilling further requirements, and about 10% are not certified due to major issues. The 2023 round dispatch was completed in mid-July with analysis and preparation of reports underway.

The program is run annually because:

- Processes drift: changes occur—often unconsciously or from a change of equipment—that can lead to counts being higher, lower or more variable than they used to be, even with experienced operators.
- Staff change: Experienced staff leave, new staff may even be trained by inexperienced operators who do not fully understand the principles.

Most laboratory quality assurance programs are run on an annual basis for similar reasons.

When reviewing which WEC providers have had issues there is no predisposing factor. Government, university, veterinary pathology, and large throughput dedicated commercial WEC providers are just as likely to have issues as one- or two-WEC operator veterinary clinics, stock agents or industry consultants.

Learning to do worm egg counts can be akin to the game of 'Chinese whispers', where the operator has been taught third- or fourth-hand away from an initial expert. Likewise, pulling out the old veterinary school notes does not guarantee a successful translation into good practice.

The best way to learn is from someone with all of these abilities:

- Demonstrated consistently good results in the ParaBoss WEC QA Program.
- A thorough understanding and ability to teach the principles on which a worm egg count is based.
- The ability to identify issues with an operator's process and then adjust that process within that laboratory's facilities and equipment.

By participating in the WEC QA program you will be able to see exactly how you and your staff compare, and you are provided with written resources to assist you, referrals to potential trainers and guidelines on conducting a self-audit with a ParaBoss-certified laboratory. Clinics that only do small numbers of WECs should seriously consider participation at least once for an initial benchmarking and the resources and then conduct annual self-audits.

Participant fees are currently $350 per business plus $20 per operator (GST inclusive).

The program was developed by the University of New England (UNE) under the ParaBoss Phase II project funded by Australian Wool Innovation and Meat and Livestock Australia. Samples were previously supplied by DPIRD WA, Albany, until retirement of their key staff. In 2022 UNE developed, funded and now operates a new sample preparation, packaging and dispatch methodology that has been very well-received by participants due to greater timing flexibility from increased sample longevity and no requirement for changes to each operator's own process. The analysis continues to use the statistical methodology published by Andrew van Burgel, DPIRD WA(1).

Conclusion

The ParaBoss WEC QA Program confirms that a significant number of WEC providers each year may be providing incorrect results to their clients and offers all WEC businesses the means to benchmark themselves and improve if required, and be recognised and promoted if meeting ParaBoss standards.

It is recommended that all veterinary businesses that provide regular WEC services participate annually, with those doing relatively few WECs participating at least once, followed by self-audits.

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Worm control in goats: a difficult, but much-needed skillset for veterinarians

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Introduction

Controlling worms is frustrating for goat owners as effective use of anthelmintics is legal only with prescription from their veterinarians. However, this provides veterinarians with the opportunity to supply worm management, prescribing, and dispensing services as part of a broader goat-health service.

The problems

- Almost all effective uses of anthelmintics require a veterinary prescription.
- Significant levels of drench-resistant worms are likely in all Australian goats.
- Pour-on products are convenient, but their field effectiveness is questionable and multi-active options are limited.
- Not all products are sold in small volumes to suit smallholders.
- Cheaper drenches are often older, single actives with more resistance to them.
- Many goats are in coastal areas in small herds where favourable climate, poor infrastructure, and overstocking leads to the year-round threat of haemonchosis.
- Veterinarians prescribing off-label bear the risk when deciding withholding periods.
- Most veterinarians have a poor knowledge of contemporary, effective, integrated worm control practices.

The solutions

A bona-fide client-veterinarian relationship is essential for goat owners to use anthelmintics legally at appropriate dose rates. But prescriptions should not come alone; with good quality advice owners, the goat industry, and the related sheep industry, are better off.

Veterinarians who gain the required knowledge can provide and charge for sound integrated worm management services and products as an adjunct to provision of other goat veterinary services (with the benefit of no after-hours work).

Veterinarians can gain the required knowledge, while accumulating 30 CPD points, from the full *ParaBoss Certificate in Sheep Parasite Management* and the ParaBoss Advisor Training recorded webinar: *Goat drenches: What, how much, how long?*

Potential veterinary services from a sound knowledge of worm management

- Provide ad hoc worm management advice.
- Develop and oversee tailored integrated worm management programs.
- Assist goat owners with on-farm product trials for Barbervax®, BioWorma® and Copper Oxide Wire Particle (COWP) boluses.
- Provide worm egg counting services.
- Conduct drench efficacy testing.
- Provide off-label prescriptions*, which must include suitable dose rates, withholding periods and, where applicable, meet milk withholding periods.
- Dispense small amounts of anthelmintic products*.

*Only veterinarians can legally do these.

General recommendations veterinarians can provide to clients

- Drench resistance is widespread; do not rely on anthelmintics alone.
- Use pasture spelling and provide as much browse as possible.
- Regularly monitor worms using WEC, weight, condition score and conjunctiva colour.
- More accurately estimate weights with scales or body measurement calculations to ensure correct anthelmintic doses.
- Use a dose rate of 1.5 times the label rate (except for copper boluses, BioWorma® and Barbervax®—use the label rate).
- Avoid organophosphate (naphthalophos) in small herds due to the risk of toxicity.
- Take care not to overdose, particularly with levamisole, abamectin and closantel.
- Conduct pre- and 14-day post-drench WECs (DrenchChecks) regularly.
- Always drench with effective combination products (or concurrent use of products).
- Use sheep anthelmintic products; don't use cattle pour-on products.

Anthelmintics for goats

Goats metabolise anthelminthics faster than sheep and cattle, so need a higher dose rate of product. Dr Emma Doyle[1], University of New England (UNE), administered various cattle and sheep anthelmintics to goats infected with pure strains of susceptible *Haemonchus* and *Trichostongylus* larvae. Similar blood concentrations of the actives were found in goats given 1.5 times the label dose rate to blood concentrations at label dose rates recorded for sheep and cattle. This supports other sources that recommend doses of 1.5 times the label dose rate.

However, one exception was found in Doyle's study: Cydectin Pour-On for Cattle ad Red Deer®, containing moxidectin, failed to be effective even at 2.5 times the label dose rate. Yet the oral and injectable sheep Cydectin® products and the doramectin and eprinomectin cattle pour-on products studied were all effective on susceptible worms at 1.5 times the dose. The currently unknown reason for this discrepancy may be due to the ability of goats to absorb this specific formulation.

Additionally, when the various pour-ons were used at 1.5 times the label dose against field infections (also containing *Haemonchus* and *Trichostrongylus* species, which could have contained drench-resistant worms), the effectiveness was very poor, at 25%–30%. Even at 2.5 times the dose, only 30%–50% effectiveness was achieved. Whereas oral formulations of moxidectin, monepantel, and a derquantel-abamectin combination, as well as an injectable moxidectin all achieved 99–100% effectiveness at day 14 after drenching.

ParaBoss[2] recommends that combinations (or concurrent drenching) with a number of the most effective anthelmintic actives for a property are the best way to both overcome and slow the further development of anthelmintic resistance. As almost all pour-ons are single-active products and based on their poor in-field results in the University of New England study, the use of cattle pour-ons cannot be recommended for goats.

The take-home message for goat anthelmintic treatments is to use an effective sheep combination product (or concurrent treatments) at 1.5 times the sheep dose rate.

Where effectiveness of the actives has not been recently tested on the specific property, assume that no active is entirely effective, especially the older actives. In these situations, it may be prudent, especially for predominantly *Haemonchus* infections, to use at least 3 actives (from different drench classes).

A quarantine drench for introduced stock should contain at least 4 actives, containing at least 1 of the newest actives: monepantel and derquantel. This will require concurrent use of more than one product.

Toxicity of drenches has also been reported in goats, but has typically occurred from overdosing, or when goats are in very poor condition, or after prolonged transport.
The actives of most risk are naphthalophos, levamisole, closantel and abamectin.

Considering that many goats are in small herds or are pets, and facilities for handling these goats are often poor, the author recommends that drenches containing naphthalophos, an organophosphate, are never used or recommended in small herds as mis-drenching into the trachea could occur more easily, which results in the swift death of affected animals.

When using concurrent drench products consider double ups of actives. In the author's experience with sheep, using doses appropriate to the weights has resulted in no toxicity when both products contain abamectin, or one contains abamectin and the other moxidectin (including long-acting injectable formulations).

With care and forethought, toxicity can be avoided because it generally relies on two or more of these factors coinciding: overestimating animal weights; giving a bit more product "for good measure"; the lightest animals receiving the same as the heaviest with a wide weight range in the group; miscalculation of the dose rate; distractions or poor technique that results in individuals receiving a second and sometimes third dose; and concurrent drenching with abamectin/moxidectin in both products.

Veterinarians must also provide a Withholding Period (WHP) [but not an Export Slaughter Interval (ESI)] when prescribing off-label use of anthelmintics. ParaBoss cannot provide WHPs for the 1.5 times label rate use as there are no published results. However, for the few actives studied by UNE the residue depletion times for goats given this rate was quite similar to sheep receiving the label rate and fell within the sheep WHP. This knowledge, combined with a generous buffer period, could assist when using professional judgement to decide on a WHP, however, this would only be applicable where the product actually has a Maximum Residue Level (MRL) determined for goats (or "all mammals").

Goat MRLs exist only for levamisole and morantel; moxidectin and abamectin; and albendazole, fenbendazole, oxfendazole and triclabendazole. Monepantel, derquantel, closantel, eprinomectin, doramectin and naphthalophos do not have goat MRLs. Therefore, the default MRL for these is "not detectable"— effectively zero. If prescribing these, consider the likelihood of the animals (or their by-products, e.g. milk, cheese etc) entering the food chain, consider the sheep or cattle WHP and particularly the ESI, which is often longer than the WHP, and add a much longer buffer period to create a WHP with which you are comfortable.

Conclusion

Veterinarians can play an important role in worm management for goats that can also build their service repertoire. However, it is a complex topic and most veterinarians need to substantially increase their knowledge, not only to learn effective use of non-chemical management strategies, but to prescribe chemical control appropriately. ParaBoss provides two key training resources to assist; the WormBoss unit from the ParaBoss *Certificate in Sheep Parasite Management* and the ParaBoss Advisor Training recorded webinar: *Goat drenches: What, how much, how long?*

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Insecticide resistance and prevention of flystrike: the science and the practice

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Introduction

Sustainable parasite control relies on integrated parasite management principles, including, where possible, the adoption of non-chemical controls to reduce reliance on chemicals. However, the availability of effective insecticides for the protection of sheep against flystrike by the Australian sheep blowfly (*Lucilia cuprina*) remains critically important for Australian sheep producers and for sheep welfare.

The number of currently available insecticides is limited, and it is therefore important that we preserve the efficacy of our current products for as long as possible. We need to use chemicals in a way that minimizes the risk of selection pressure leading to resistance[1].

Dicyclanil in particular has long been a critical molecule in the prevention of flystrike, and the development of resistance to dicyclanil is an increasingly important challenge for producers and advisors.

CSIRO and Elanco Animal Health are investigating insecticide resistance in the Australian sheep blowfly (*Lucilia cuprina*) in order to increase our understanding of the underlying mechanisms of resistance and its development. The work to date reveals the enzyme detoxification pathway likely to be responsible for resistance to dicyclanil and provides evidence of cross-resistance with imidacloprid and, to a lesser extent, to cyromazine[2].

This has important implications for resistance management. We can take steps to avoid or minimize selection pressure for resistance in the way we recommend which products are used and the manner in which those products are used. Consideration must be given to the class of insecticide, frequency and timing of treatment within each wool-growing season – along with consideration as to the presence of other parasites and products used for their control.

Resistance profiles of field strains

Blowflies collected from struck sheep at six locations in NSW (Figure 1)[3] have been examined in this study. We have used *in vitro* bioassays to measure the sensitivity of these field-derived strains to various flystrike insecticides: dicyclanil, cyromazine, imidacloprid, ivermectin and spinosad. The strains have all shown significant levels of resistance to both dicyclanil and imidacloprid, with resistance factors at the IC_{50} ranging from 9-26-fold for dicyclanil, and 9-17-fold for imidacloprid (Figure 2). Resistance factors towards cyromazine ranged from 3 to 6-fold. For ivermectin and spinosad, the resistance factors were low, ranging from 1.5 to 3-fold across the two compounds.

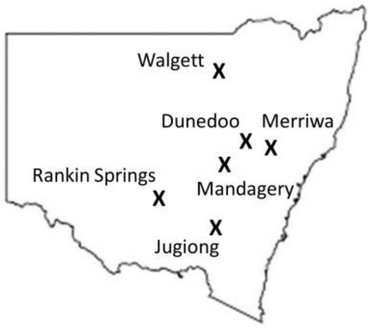

Figure 1: Locations within NSW at which the blowfly strains used in the present study were collected from struck sheep

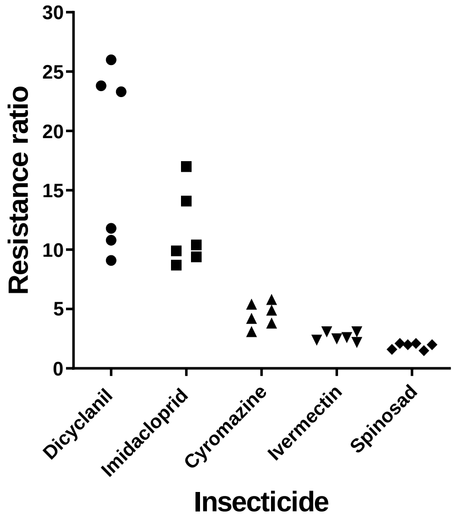

Figure 2: Resistance ratios for six field strains relative to the reference susceptible LS strain

Mechanism of resistance

Resistance to both dicyclanil and imidacloprid was suppressible by co-treating the larvae with a cytochrome P450 inhibitor, aminobenzotriazole, implicating this detoxification enzyme system in resistance to both compounds (Figure 3). In order to identify the cytochrome P450 enzyme(s) responsible for the observed resistances we have measured relative expression levels of several candidate cytochrome P450 genes in the field strains compared to our reference susceptible strain (LS). However, this analysis has not yet revealed the identity of the genes involved in the resistance.

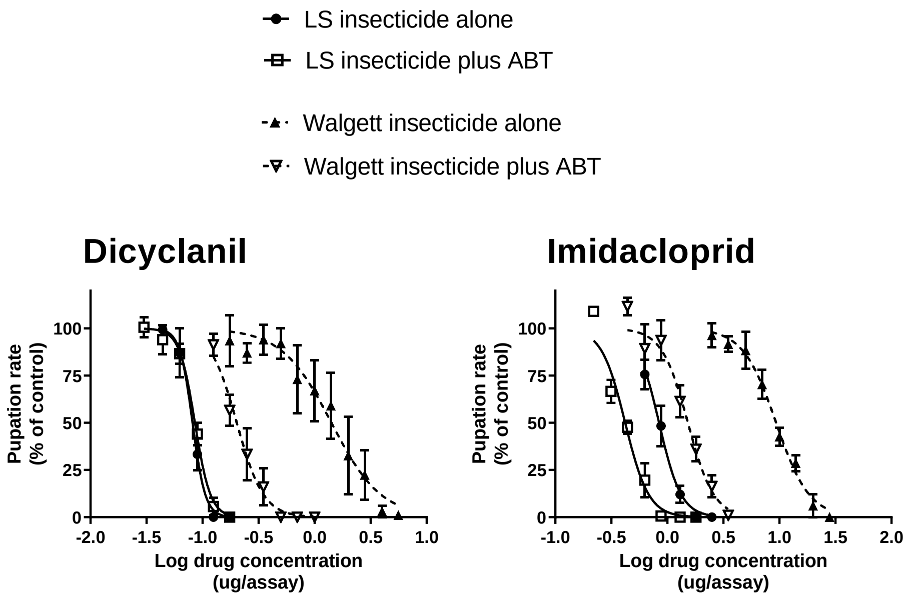

Figure 3: Effects of the cytochrome P450 inhibitor, aminobenzotriazole, on dose responses of Walgett and LS larvae to dicyclanil and imidacloprid (modified from Kotze et al 2022[2]).

Response to selection pressure

We have performed drug selection experiments in order to examine:

i) cross-resistance patterns between the various insecticides, and
ii) the relative rates at which resistance develops to the different insecticides.

These experiments have involved the exposure of fly larvae to repeated rounds of drug selection pressure *in vitro* with either dicyclanil or imidacloprid over sequential generations. Over the course of the experiments we have monitored changes in sensitivity to both the selecting chemical and other currently-available flystrike control chemicals. These experiments have been performed with several field strains as well as the reference susceptible strain (LS). Results to date indicate several important features of resistance development in the blowfly, which may have important implications at field level, for example:

i) differences between the insecticides in the rate at which the susceptible LS strain responds to selection pressure: this strain has developed resistance to imidacloprid much more rapidly than to dicyclanil.
ii) selection of the LS strain with imidacloprid has resulted in resistance to this compound alongside some resistance to both dicyclanil and cyromazine.
iii) selection of the Dunedoo strain with imidacloprid has resulted in a 3.4-fold increase in resistance to this chemical alongside a 3.1-fold increase in resistance to dicyclanil.

Field implications

With a better understanding of the underlying mechanism of resistance, risk factors in the ways selection pressure may be imposed at field level are identifiable. As a result, recommendations on which products should be used and the manner in which they are used can be tailored in order to avoid or minimize selection pressure for resistance, and hence preserve the useful life of the current flystrike control chemicals for as long as possible.

Consider the implications of sequential treatments

The risk of resistance developing is increased with the frequency with which a chemical (or related chemical) is applied.[1] Where possible, practices that preserve the current levels of susceptibility should be adopted – including fewer insecticide applications and no second treatments with the same or a related compound in the same wool growing cycle.[4] It is well known that dicyclanil and cyromazine are related compounds, and sequential use of these compounds is best avoided. However, this research provides evidence that the use of imidacloprid may impose selection pressure for development of resistance in the same way as dicyclanil – such that these compounds should not be regarded as sufficiently dissimilar to provide a valid rotation option from one another. (See Table 1 for chemical groups of products registered for the prevention of flystrike).

The duration of protection provided by insecticidal products is also an important consideration – to avoid the need for second or even third treatments within a single wool-growing season and to minimize the opportunities for selection at concentrations that are marginally effective (see Table 1).

For persistent protection, insecticide residues must remain at therapeutic levels in the fleece for an extended period – as they degrade slowly over time. At some point a concentration is reached that no longer kills all individual insects within the population. Seasonal change – along with appropriate product choice – would ideally mean that flies are no longer active when this concentration is reached.[1] Alternatively, removal of wool through shearing or crutching (subject to label wool harvesting intervals) would remove insecticide residues before this concentration is reached. Accordingly, selection pressure may be able to be actively moderated through management practices.

Selection pressure also reflects the degree of pest exposure[1] – and this is arguably lower for the sheep blowfly than for lice and roundworms – where selection may occur simultaneously and immediately at the time of treatment. Selection for resistance in the sheep blowfly depends entirely on whether blowflies and flystrike susceptible sheep are likely to co-exist during the critical intervals when resistant larvae can survive on treated sheep but susceptible types cannot.[4] This depends not only on the choice of product – and the concentration range over which resistant types have a survival advantage compared with susceptible types – but is also influenced by the timing of treatment. Again, this is able to be actively moderated through management practices.

With reliance on a single insecticide class for repeat treatments a risk factor in selection for resistance, a rotation strategy in which dissimilar chemicals are used for sequential treatments is both logical and sensible. While this may preclude the use of the same or related chemicals during a single wool-growing cycle,[1,4] it should also take into account any treatments used for the control of lice.[1]

Consider the implications of dual use chemicals

Lice treatments can select for resistance in sheep blowflies.[5] Likewise, treatment for flystrike exposes any lice present to chemical. Historically, repeat applications of organochlorines and organophosphate products targeting lice in short wool and blowflies in long wool increased the selection pressure for resistance to these chemicals. Dual use against lice and blowflies is also likely to have exacerbated resistance to diflubenzuron (benzoylphenyl ureas). Sequential treatments, whether directed at lice or blowflies, should therefore never be from the same chemical class.[1] If possible, use chemicals from different chemical groups for controlling lice and flystrike in the same year.[5]

In terms of currently available products, care must therefore be taken with imidacloprid, ivermectin and spinosad. Fortunately, the two main chemicals used for flystrike prevention, cyromazine and dicyclanil, do not have any effect against lice and will therefore not be used for dual purposes nor contribute to selection for resistance in lice.[5] (See Table 1 for for chemical groups of products with dual activity against both flies and lice).

Selection pressure for resistance in flies will be a function of the proportion of the population exposed to treatment[1] – but only at such time that selection actually occurs i.e. if and when fly activity coincides with the discriminating dose and susceptible sheep. The number of flies at the time of treatment (whether early or late) should not impact on the extent of selection pressure, so long as an effective and suitably long-lasting chemical is used. The dilution of resistance by influx of susceptible flies into the population from refugia will also influence the evolution of resistance, with mobility providing a degree of inherent refugia – despite the oligophagous nature of the parasite.[1]

Conclusion

Best practice guidelines (www.flyboss.com.au) recommend that different chemicals should be used for successive treatments in the prevention and treatment of flystrike – and to consider planned flystrike preventative treatments when selecting lice treatments.[6] The timing of treatment, consideration of seasonality and careful integration with management practices also provide significant opportunity to optimize protection against blowfly strike while minimizing selection for resistance.

Rotation Options - Table 1: Rotation options for prevention of flystrike showing length of protection, method of application and risk of selection for resistance in lice.

Length of protection	Example product	Active	Concentration	Application Method	Dual activity against flies & lice
Up to 29 weeks	CLiK Extra	Dicyclanil	65g/L	Spray-on Backliner	No
18-24 weeks	CLiK	Dicyclanil	50g/L	Spray-on Backliner	No
Up to 14 weeks	Vetrazin Liquid	Cyromazine	500g/L	Jetting Fluid	No
Up to 14 weeks	Avenge	Imidacloprid	35g/L	Spray-on Backliner	Yes
Up to 12 weeks	Coopers Blowfly & Lice	Ivermectin	16g/L	Jetting Fluid	Yes
11 weeks	Vetrazin Spray On	Cyromazine	60g/L	Spray-on Backliner	No
Up to 11 weeks	CLiKZiN	Dicyclanil	12.5g/L	Spray-on Backliner	No
4-6 weeks	Extinosad Eliminator	Spinosad	25g/L	Jetting Fluid	Yes

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mRNA vaccines made in Australia to prevent emergency animal diseases

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New South Wales Department of Primary Industries[a] (NSW DPI), Tiba Biotech[b] (Boston), Canadian Food and Inspection Agency[c] (CFIA), University of New South Wales[d] (UNSW)

An Australian RNA vaccine development pipeline for emergency animal diseases brings together a collaborative network including UNSW/NSW RNA Pilot Facility, CFIA and international partners. The program utilises a licence agreement with Tiba Biotech providing access to next generation RNA vaccines with self-amplifying mRNA technology and RNABL® dendrimer formulation (US patent, 2020). Priority targets are lumpy skin disease (LSD), Border disease (BD) and foot and mouth disease (FMD; serotypes O and A).

A BD vaccine directed against the viral surface glycoprotein is being evaluated in sheep after demonstrating protective immunity in mice. The vaccine was evaluated in sheep using different dendrimers. The preferred formulation given at 50 µg/head twice with a 5-week inter-dose interval produced strong virus neutralising titres and 7 of 8 of these sheep were protected against infection with live virus. The pestivirus AGID test for antibodies to a non-structural viral protein was positive in infected sheep but not vaccinated sheep giving the capacity to distinguish infected from vaccinated sheep. UNSW will produce mRNA constructs and establish the scale up and production pathways for dendrimer formulation. The NSW Pilot facility will be able to make vaccine in an emergency.

For LSD, six potentially protective antigens were used to generate six LSD mRNA vaccines. All six mRNA vaccines demonstrated the ability to produce their specific antigens in cell culture following transfection. These mRNA vaccines were administered to mice and antibody responses specific to their specific baculovirus expressed antigen were assessed by ELISA. Following vaccination, specific antibodies were detected by ELISA for each mRNA vaccine. Combinations of these will be assessed for efficacy in sheep and cattle (CFIA) and hopefully the Australian Centre for Disease Preparedness.

Tiba Biotech have previously produced an FMDV-O vaccine that gave protective antibody titres in pigs and this will be further evaluated using the current vaccine platform technology.

Regulatory requirements and expedited emergency registration of new mRNA vaccines for livestock are being explored with progress towards registration of the BD vaccine.

Back to the Future: non-chemical flystrike prophylaxis

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Introduction

The Australian sheep blowfly, *Lucilia cuprina*, has developed resistance to the two most widely used insecticides, which is now widespread, and of grave concern to Australian sheep producers. As a result, a variety of flystrike management strategies which reduce reliance on chemicals are being investigated.

Sterile Insect Technique (SIT)

Eradication of insects following the release of infertile individuals was first proposed in the 1930's.[1] SIT involves the mass culture of an insect pest, separation based on gender, chemical or radiation sterilisation of males and their release. Those females which mate with sterilised males will not produce fertile eggs. This technique was successful in eradicating the New World Screw Worm Fly from the southern states of the USA and has been utilised against a number of other insect pests. The use of radiation to render *Lucilia cuprina* infertile was researched in the 1960's[2] and studies on SIT to achieve eradication commenced in Australia in the 1970's[3]. We investigated this technique in the laboratory and in sheep pen trials where we proved that gamma irradiation effectively sterilised both sexes without reducing their fitness, longevity or the ability of males to compete with wild type males. We developed *L. cuprina* specific procedures for fitness determination, including the development of an apparatus to measure a fly's ability for flight.

Field Trials

The first property based trial, over summer/autumn, was conducted in the Northern Tablelands (NT) (n=2760) and the second in the Yass Valley (YV) over spring/summer (n=1250). Both trials had a control property located more than 9kms in a direct line from the release property. These trials used the absence of flystrike on resident sheep as an indicator of the success of the releases and the presence of flystrike on the control properties as evidence of fly challenge. We achieved zero strike following 3 releases at the NT property but were subsequently stymied by flooding events at EMAI and Armidale. In the YV trial, we demonstrated that *L. cuprina* initiated flystrike could be completely prevented from mid-September 2022 until the 2nd of January 2023 by the fortnightly release of 30,000-60,000 infertile males when commenced prior to emergence of the over wintered population. Following the end of the final releases' "protection" period, and while waiting on shearing, 13 breech strikes occurred in 8 days on the release property and 18 in 15 days on the control property, This demonstrated the constant challenge provided to the release property from neighbouring sheep properties. These "proof of concept" trials provided valuable data on the rearing conditions, age, quantity and quality of the irradiated flies and favoured release conditions for the successful non-chemical prophylaxis of flystrike at the property level.

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Meat & Livestock Australia: sheep and goat research and development update

M Smith

Meat & Livestock Australia, North Sydney NSW

Meat & Livestock Australia (MLA) is a service provider to the red meat industry with a vision of enduring prosperity for the Australian red meat and livestock industry. MLA is a not-for-profit organisation funded through transaction levies paid on livestock sales, the Australian government and contributions from industry partners. The two key roles of MLA are to (1) undertake research, development and adoption programs to increase on-farm productivity, sustainability and profitability to support the industry's prosperity and (2) conduct marketing activities to grow domestic and international demand for Australian red meat.

This presentation will (1) provide an overview of the current focus areas across the sheep and goat productivity programs, and (2) deliver a summary of key research projects from both programs and highlight pathways for engaging with MLA.

Reported diseases of interest in Victorian small ruminants (2020 to 2023)

B Squire

Agriculture Victoria, Swan Hill VIC

Property identification codes are required for any properties that may graze or keep livestock, even if it is a sole animal or the animal is present for less than a day. Property identification codes are free in Victoria and can be obtained via Application-for-a-livestock-property-identification-PIC.docx or https://pic.agriculture.vic.gov.au/

The Victorian Significant Disease Investigation (SDI) program aims to boost Victoria's capacity for the early detection of such diseases in livestock and wildlife by increasing the participation of vets and subsidising the cost of investigating significant diseases. Subsidies are available from Agriculture Victoria for the initial field investigation, including clinical and post-mortem evaluation, laboratory testing and a follow-up investigation of significant disease events in livestock and wildlife.

Notifiable diseases in Victoria that could affect sheep, camelids and/or goats include anthrax, CAE, leptospirosis, listeriosis, OB, ovine footrot, JD and salmonellosis. Exclusion testing is often performed for BTV, FMD and TSEs. Notification can be via the EAD hotline (1800 675 888), the Notify Now app or email using the Notification-of-the-presence-or-suspected-presence-of-a-disease form.

For National accreditation/assurance programs flock/herd status can be checked via:

- Search for an Ovine Brucellosis Accredited Flock

- Search for a Sheep JD MAP Flock

- Search for a Goat MAP Flock

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Taking the Q (Query) out of Q fever, 2016-2022: summary of key project findings

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Q fever is an infectious disease of humans and animals caused by the bacteria *Coxiella burnetii*. While many people with Q fever are asymptomatic or have only mild symptoms, for some, there is a prolonged, serious and debilitating illness. The signs of Q fever in animals range from none at all, to reproductive losses and milk production impacts. In Australia, Q fever is the most common of the notifiable zoonoses.

In The Netherlands in 2007-2010 there was a large outbreak of Q fever associated with intensively managed dairy goat herds resulting in around 4000 confirmed human cases. With increasing intensification of the Australian dairy goat industry, conducive climatic conditions and some of the highest rates of human infection in the world, the Taking the Q (query) out of Q fever project was conceived to provide information to reduce the risk of a similar outbreak occurring in Australia.

Collaboration between the project team - i.e., the four partner universities (The University of Melbourne, The University of Queensland, The University of Adelaide and Charles Sturt University), the Australian Rickettsial Reference Laboratory and industry partners (Meredith Dairy and GoatVetOz) enabled findings to be generated under three research themes: (1) improving knowledge and management of coxiellosis in Australian dairy goat herds; (2) understanding the distribution of Q fever in the environment; and (3) development of One Health structures to support improved Q fever management across the human, animal and environmental health sectors.

Through the first research theme, the project generated extensive knowledge and industry-implementable processes to improve the management of coxiellosis-risk in Australian dairy goat herds. The project demonstrated, for the first time, that *C. burnetii*-positive does produce less milk than their *C. burnetii*-negative herd mates.[1] Beyond the public health imperative, this finding means that dairy goat herd managers have an economic incentive for preventing the introduction of coxiellosis into their herds or controlling and eradicating the disease in endemic herds. Fortuitously, a survey of the industry identified a relatively low prevalence of coxiellosis across Australia's commercial dairy goat herds,[2] which supports implementation of biosecurity practices and disease freedom assurance programs. [3] A series of detailed risk assessments with managers of *C. burnetii*-negative farms identified that each had a low risk of introduction but high risks of exposure of livestock on the farm and moderate to high consequences if the disease was introduced.[3] An Information Management System (IMS) developed by the project team provides the dairy goat industry with a tool to measure herd performance, identify performance shortfalls, ultimately improving their productivity and profitability.[4] Better information management will allow metrics such as abortion rates and failure to kid rates to be used as indirect indicators of the presence disease on farms. Guidelines have been developed around the testing that needs to be done to allow herd managers to have confidence that their herds are free of *C. burnetii*.[5]

To better understand Q fever in the environment (Research Theme 2) guidance on environmental sampling techniques and methods, critical to informing the subsequent environmental contamination studies were developed[6,7,8] Intensive sampling around a farm in which an intensively managed dairy goat herd known to be *C. burnetii* positive was kept showed little evidence of bacteria beyond the immediate vicinity of the sheds in which does were housed.[9] The conclusion from this work was that residential zoning in rural areas need to be managed to ensure that there is a sufficient physical buffer between locations where animals are housed and areas of human settlement. By investigating a range of wildlife[10] and pest species, the project filled knowledge gaps and supported ecological approaches to studies of infectious disease transmission. For example, analyses of rabbit[11] and deer[12] samples showed that while both species were unlikely to contribute significantly to the transmission of *C. burnetii* to livestock (or people), the geospatial distribution of positive samples around the *C. burnetii* positive farm described earlier is consistent with seropositivity documented for other animal species.

A range of activities contributed to Research Theme 3, which developed strategies to support Q fever management across the animal, human and environmental health sectors. Findings from a systematic review were corroborated with data generated from expert elicitation workshops, highlighting how economic, political and socio-cultural forces (i.e., factors that govern the way that people live and work) intersect with transmission dynamics to drive the occurrence of Q fever outbreaks.[13] A range of qualitative methods explored the limitations for veterinarians around the diagnosis of coxiellosis in animals, the convoluted diagnostic journeys of many human Q fever patients, and key 'decision points' in reporting pathways that are important with respect to the identification of cases in animals and humans, and where targeted education and communication would influence the likelihood of early identification of cases. From this work, the project team developed strong, evidence-based recommendations that fit within current systems but value-add to facilitate marked improvement in the capacity for early identification and prevention of large-scale Q fever outbreaks in humans.

Q fever is a disease that disproportionately affects rural communities and has long been a concern for primary producers. In addition to substantial public health learnings around the management of Q fever across the animal, human and environmental health sectors, the activities undertaken through this project have generated significant productivity and biosecurity improvements for Australian primary producers.

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Are foot diseases preventable in sheep?

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Introduction

Lameness is a primary production-limiting condition in small ruminants and a common reason for producers to seek veterinary advice, especially in above-average rainfall seasons. Costs associated with lameness were estimated to be $215M and ranked sixth among endemic diseases of sheep affecting the Australian red meat industry in 2022.[1] The resolution of lameness is rarely simple or wholly effective. It may involve foot trimming, foot bathing, antibiotics, analgesics, and vaccines. The focus of this paper is to explore the opportunity to prevent foot diseases, including footrot, ovine interdigital dermatitis (OID), contagious ovine digital dermatitis (CODD), foot abscess (toe and heel), and shelly toe.

Aetiology and epidemiology

Contributing factors common to these foot conditions include wet soil, often overgrown and misshapen hoof horn, various free-living microorganisms, and evidence of nutritional and/or metabolic disturbance. Overgrown and misshapen feet can result from standing in moist conditions for extended periods with an associated failure to wear hoof horn evenly and possibly a genetic predisposition. In addition, gait anomalies may contribute to a change in standard foot posture and hoof wear. Further complications can include nutritional deficiencies predisposing to invasion of hoof tissue by soil-borne microorganisms and metabolic disturbances disrupting horn formation.

Invariably, the favourable conditions of warmth and moisture predispose to the incidence of both contagious or incidental lameness associated with microbial and parasitic invasion of hoof tissue. Various soil-borne microorganisms can invade the interdigital space and sensitive laminae due to continuous wetting and developing cracks in the hoof horn to cause inflammation, leading to an abscess. Common free-living microbial agents include *Fusobacterium necrophorum* and *Trueperella pyogenes,* associated with foot abscess and ovine interdigital dermatitis (OID), colloquially referred to as scald. Depending on virulence, these conditions, including *Dichelobacter nodosus*, may lead to more severe interdigital inflammation and underrun of the soft heel and hard toe horn, known as footrot.[2,3] Another similar condition not known to occur in Australia but associated with spirochaete (*Treponema spp*) hoof infection is contagious ovine digital dermatitis (CODD) in the United Kingdom. This presents initially as an inflammatory lesion at the coronet and descends to invade the sensitive laminae of the wall horn.

Other less common infectious foot lesions not dependent on warmth and moisture include *Dermatophilus congolensis* infection at the coronet, referred to as strawberry footrot; an infection with a similar appearance at the coronet caused by the orf virus, referred to as scabby mouth of the foot; and parasitic infections caused by *Strongyloides* and trombiculid mites. Non-infectious foot conditions include trauma, overgrown horn, granuloma, interdigital hyperplasia, shelly hoof, white line separation, and grass seeds. Emergency animal diseases that may present with foot lesions include foot and mouth disease, screw worm fly, and bluetongue.

All breeds of sheep are susceptible to hoof conditions, but incidence may vary with individual genetic predisposition, management, and nutrition. Estimates of heritability for footrot in Merinos range from 0.09 – 0.41 depending on how the infection was acquired and variation between bloodlines.[4] Management procedures that can influence foot conditions include excessive foot trimming and foot bathing, which are thought to predispose to shelly hoof, granuloma, and white line or toe abscess.[5] In addition, prompt treatment of footrot and CODD are believed to reduce granuloma prevalence.

Nutrition is recognised to play a key role in maintaining hoof health. Dietary protein, energy, and fibre balance are vital to rumen and hoof health. Excessive protein intake can result in high blood ammonia, reducing immunity and disrupting hoof wall integrity.[6] Zinc, copper, and selenium contribute to hoof health, growth, disease resistance, bone and muscle development, and fertility. [7,8] Selenium supplementation has improved recovery from footrot, and adequate intake reduced susceptibility.[9] Biotin is also recognised to assist hoof health and animal productivity.[10] Desired nutrient levels for livestock are well established, but ensuring all animals maintain balanced nutrition in pasture-based systems is challenging.[8] Nutrient availability varies within and between paddocks and seasons. Rotational grazing combined with periodic nutrient monitoring in feed and animals is desirable to detect dietary inadequacies before they cause production loss. Periodic monitoring of plant tissue provides an estimate of the 16 minerals recognised as essential in the ruminant diet and where supplements may be beneficial. Blood and liver biopsy sampling enables the assessment of animal trace element status and specific needs for supplements.

Factors recognised as contributing to the incidence of foot conditions include above-average rainfall and lush pasture, increased risk of mineral deficiencies, high stocking density leading to soil pugging and softening of the interdigital skin, advanced pregnancy and body condition increasing hoof weight-bearing, high protein diets and elevated blood ammonia; reduced cud chewing on lush pasture contributing to a lower rumen pH, and metabolic disturbance resulting in subacute ruminal acidosis and laminitis. An anaerobic interdigital space in cold, wet conditions allows pathogens to invade hoof tissue aided by vasoconstriction, poor circulation in peripheral hoof tissue, high blood urea nitrogen and immunosuppression, and restricted hoof oxygenation and vitamin and mineral supply. The consequent loss of tissue integrity predisposes to OID, foot abscess, or footrot, depending on which pathogens are present.

Control and prevention

Foot trimming, foot bathing, and antibiotics are producers' most common strategies to control and hopefully cure foot conditions. In the case of foot abscess, when lameness is recognised, irreparable damage may have already occurred to the hoof, leading to permanent disfigurement and disability.[11] Also, there is ample evidence that routine use of antibiotics and foot bathing should be considered outside of good practice for managing lameness.[12]

Treatment aims to detect and correct the cause of the foot condition early to minimise pain and lameness. Specific conditions and treatments include shelly hoof – pare the outer separated wall to prevent entrapment of foreign material; foot abscess – facilitate drainage followed by antibiotics and anti-inflammatories; granuloma – treat the underlying cause, clean, and disinfect including antibiotics and anti-inflammatories; CODD – like granuloma as well as isolation; and footrot – three options including antibiotics, vaccine, and footbathing individually or in combination.

The most cost-effective antibiotic for treating footrot is oxytetracycline, with greater than 90% efficacy as a single dose and placing the sheep on grating for 24 hours to allow the feet to dry away from contamination.[13] The use of multi-valent vaccines to limit disease spread during high-risk periods has been a common practice for many decades, while more recent developments of mono- and bi-valent vaccines have enabled eradication in flocks with few strains of footrot.[14] Extended footbathing using 20% zinc sulphate and a wetting agent also eradicates footrot. One approach involves footbathing all affected mobs for 1 hour every 3-4 weeks at least 3 times during spring. As with all treatment programs, it relies on careful diagnostic foot paring, a diligent bathing and quarantine procedure, and meticulous follow-up inspections.

A combined approach, the five-point plan, best summarises a clear strategy for sheep producers to manage footrot.[15] This includes the initial culling of chronically lame sheep to build flock resilience, quarantine to prevent disease challenges, rapid treatment to stop the infection cycle, avoiding disease spread with strategic footbathing, cleanliness, and biosecurity, and vaccination to treat and prevent disease.

Ultimately, lameness can be minimised by focussing on foot health maintenance. This requires adopting several strategies, including monitoring to maintain a nutritionally balanced diet, grazing management to minimise conditions conducive to disease incidence, and biosecurity to prevent disease incursion. Specific strategies are regular plant tissue and blood tests to assess the nutrient status of livestock, monitoring body condition/herbage mass and feed budgeting to optimise nutrition appropriate to age and physiological status, providing suitable supplements in a practical form, and other husbandry procedures as required.

Conclusion

The ability to prevent foot diseases in sheep is determined by attention to detail and the environment. Sheep producers can minimise foot conditions by attentively monitoring animal nutrition and biosecurity and adopting strategic preventative husbandry procedures, including regular mob inspections and prompt treatment of lameness.

Conflict of interest

The author of this paper does not have a financial or personal relationship with other people or organisations that could inappropriately influence or bias the paper's content.

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Hypocalcaemia in ewes: a Central NSW perspective

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Introduction

There are several disease entities associated with hypocalcaemia in sheep. In the author's experience, hypocalcaemia occurs in sheep:

1. due a dietary deficiency,
2. due to short term feed deprivation and other stressors,
3. in pregnant and lactating ewes due to an inability to meet calcium demands,
4. in association with osteoporosis in young sheep,
5. induced by toxic plants (especially containing oxalates) and vitamin D deficiency,
6. secondary to other diseases such as pregnancy toxaemia and foot abscess.

Of course, these conditions may exacerbate each other. For example, sheep suffering from a chronic dietary calcium deficiency are more susceptible hypocalcaemia due to short term stressors.

Discussion

Spontaneous hypocalcaemia is a major cause of perinatal ewe mortality in Southern Australia [1 2 3 4 5]. In 1988, Caple estimated that between 100,000 and 300,000 pregnant ewes died of hypocalcaemia each year in Victoria with further losses of lambs in treated and recovered and sub clinically affected ewes [2]. The 'most dramatic losses' occurred on lush feed following the droughts (as occurred in 1938 and 1983), either spontaneously or exacerbated by pre-lambing droving [6] or crutching [7] but substantial losses also occurred during winter and spring in normal years when nutritional intake seemed adequate. More recently it has been reported that both ewe mortality, bone fragility and subclinical hypocalcaemia are an increasing problem in Victoria [5]. Lean (2023) attributed this to increasing calcium demands on highly productive pasture systems especially below the 34th parallel.

The author saw numerous cases of hypocalcaemia in drought fed pregnant and lactating ewes in 2005. These cases all occurred in calcium supplemented ewes with no evidence of bone depletion, so a failure of homeostasis was considered [8]. However, it may simply have been due to unrecognised long term calcium depletion.

Spontaneous hypocalcaemia is rare problem in pregnant and lactating ewes in Central NSW on pasture. However, it can occur when ewes are drought fed on calcium deficient rations, when ewes are graze plants containing oxalates and in pregnant and lactating ewes grazing cereal crops without adequate mineral supplementation. Hypocalcaemia is more common in late pregnant ewes that are subject to stressors and inanition.

It has been suggested that spontaneous hypocalcaemia may be more of a problem in Southern Australia than on Central NSW due to decreased winter sunlight and therefore reduced vitamin D levels in ewes below the 34th parallel [5]. This is plausible because vitamin D has a well know role in calcium metabolism and is more deficient in higher latitudes. However, as suggested by Johnson (Bill, pers comm), it may in part be because southern grazing systems may be more productive, (both ewes and pastures) placing higher calcium demands on ewes, than those in Central NSW. Other factors such as the amounts of calcium and phosphorus in pastures and the dietary cation anion balance may contribute.

Subclinical hypocalcaemia can occur and may contribute to uterine inertia and therefore dystocia and to reduced gut function. This requires further investigation.

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