



Final report

B.GOA.0132- A review of internal parasite management and control in the Australian Goat Industry

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Abstract

Management of internal parasites and the impact on animal health and productivity is an ongoing struggle in the Australian goat industry. Three intersecting issues impact on this battle: the reduced capability of goats to suppress internal parasites compared to other ruminants, the lack access to effective, registered anthelmintics and other modalities to reduce animal worm burden, and the complex nature of the industry. This review investigates all three and seeks to recommend options and opportunities for the goat industry to invest in solutions.

The consulting project comprised a technical review of the latest published literature (as well as websites and other forms of information available to producers), a series of online workshops and industry consultations and direct interviews. In a similar approach to that utilised by Lyndal-Murphy et al (2007) the technical review was not designed to be a comprehensive literature review but rather a situational analysis of the current industry, its issues and challenges.

Our interviews, workshops and investigations unfortunately showed that little has improved since the last review, and indeed some aspects of the industry are worse off in terms of animal health and productivity, in relation to internal parasites. New products (drenches and other remedies) continue to be developed and registered for sheep but not goats, so information and access remains poor, while at the same time, resistance to the few remedies registered in goats is increasing. New communication technologies that could make remote access to veterinary support easier has not eventuated (as a business model). With this limited access to products and information, has emerged a plethora of misinformation, illegal recommendations and pseudo-medical remedies, primarily from social media, which drowns out the limited goat-specific information provide through reputable sources. These reputable sources are also legally limited to only recommending registered products, which may no longer be efficacious or the best recommendations under given circumstances.

All of this is not to say that improvements cannot be made. This report and the accompanying technical review provide a wide range of recommendations: short, medium and long term, inexpensive and expensive, that have the potential to make incremental and significant changes to the issues that challenge the sectors. We were constantly impressed by the passion, intensity and commitment of the goat industry stakeholders we encountered, and this alone suggests a bright future for this diverse and interesting industry.

Executive summary

This project aimed to provide the Australian Goat Industry and MLA with a snapshot analysis of how producers are managing internal parasites and develop recommendations on how improvements could be made. MLA previously funded a similar investigation into this area titled “Options for the control of parasites in the Australian Goat Industry: A situational analysis of parasites and parasite control” MLA Final Report B.GOA.0014 (Lyndal-Murphy et al, 2007a). The Technical Review builds on this previous work, updates the research it examined and provides additional and recent industry context. This supplementary report combines the findings of the Technical Review and compares this with the results of industry consultation, to develop a range of recommendations for industry and MLA.

The total consulting project comprised a technical review of the latest published literature (as well as websites and other forms of information available to producers), a series of online workshops and industry consultations and direct interviews. In addition, the review team were able to access the results of two surveys being undertaken by Australian researchers and included preliminary findings. The team have also updated the industry reference (Going into Goats-Module 9) and developed a series of slides to support the work of ParaBoss.

Since the previous review, there have been few innovations to make the role of producers managing the health of their animals easier. There are currently seventeen products based on six actives, registered for use in goats, with all but one of the actives known to have resistance levels in the moderate to high level across most farms. In summary:

- Producers have limited access to registered anthelmintics that work well enough, and many are turning to chemicals not registered for use in goats.
- The only legal way producers can legally use unregistered chemicals is via off-label prescription from vets, but producers report difficulties getting to vets, obtaining advice and WHPs from vets, or costs of vets.
- Goats metabolise and excrete differently to sheep. There is limited published information available. (MLA funded a study in 2021 to address this in part). Vets and producers have limited information on which to base dose rates, residue depletion rates and withholding periods. This presents a potential risk of residue detection in goat products.
- Anthelmintics alone are not enough to control internal parasites. There are alternatives and supportive non-pharmaceutical options available but, in many instances, there is a need for more information of use in goats under Australian grazing conditions.
- Much of the industry needs to undertake more frequent testing of worm burdens (FECs). Testing of parasite burdens in animals and pastures relies primarily on old technology that is not easy for producers to use. There is a need for fast, cheap and easy to use testing.

The recommendations provided in this document, if supported and implemented could lead to a significant improvement in both animal health and productivity in the industry.

Table of contents

Abstract	3
Executive summary	4
1. Background	7
2. Objectives.....	7
3. Methodology	8
3.1 Technical Review	8
3.2 Workshops, surveys, and interviews	9
4. Results of Industry Consultation and Investigation.....	9
4.1 Current Product Use.....	9
4.2 Vet access and vet knowledge.....	10
4.3 Producer knowledge	11
Worm burden monitoring: Faecal Egg Counts and Resistance testing	12
On-Farm Strategic and Integrated Management.....	13
5. Strategies for a better future	13
5.1 Registration of a new chemical anthelmintic product for Goats	13
5.2 Alternatives parasite control options	14
Copper oxide wire particle (COWP) bolus products:	14
Vaccines	15
Condensed Tannins (CTs):	15
Pasture burden targets:.....	16
Duddingtonia flagrans	16
Bacillus thuringiensis (Bt).....	17
Chryseobacterium.....	17
Novel concepts	17
5.3 Improved vet access and utilisation.....	17
5.4 Improved Producer Knowledge: Tailored communication and extension	19
Via ParaBoss	19

Social Media	19
Small Farm Plans.....	20
5.5 Better testing for parasite burdens: whys and hows	20
6. External communication and lobbying	21
7. Conclusion	21
7.1 Key findings	22
7.2 Benefits to industry.....	22
8. Future research and recommendations.....	23
9. References.....	25

1. Background

The consensus across the goat industry is that battle against internal parasites is being lost in many enterprises although the perceived reason for this position is due to a range of complex and interconnecting issues as diverse as the industry. Control of internal parasites in goats is one of life-long and herd wide management. The central component for control gastrointestinal parasites has been with chemical parasiticides (directly targeting the worm burden within the animal) and through management of the parasite lifecycle (via practices that interrupt this lifecycle during its pasture living phase). The former is complicated by a lack of access to reliable and efficacious products, and the later through suitability of practices across a very diverse range of producers (both in scale and activity).

The lack of registered product label claims and instructions for use in goats (compared to sheep or cattle) has resulted in scenarios where:

- The limited products that are available to producers and registered for use in goats are old, have significant levels of parasite resistance and product ineffectiveness, putting animals' safety and productivity at risk.
- Goats are being treated with products not registered for goats, at untested dose rates, or with registered products at higher than label dose rates, leading to the real risk of residues in meat and milk.
- Goats are being treated off-label with products either under veterinary advice or in the absence of veterinary advice; with assumptions being made regarding dose rates, efficacy and withholding periods, in the absence of goat-specific information.
- Goats are being treated with untested home remedies, unregistered products, and products not intended/unsuitable for these uses, putting the animal's health at risk.
- In some instances, producers are choosing not to treat their animals leading to losses in productivity, and potentially poor health outcomes or even death.

There are proven pasture management activities (aiming to control pasture mat contamination and therefore minimise reinfection of animals with larvae from within the pasture) include managing stocking density, browse feeding, cross-grazing, and paddock spelling. All with the aim of stopping the parasites completing their lifecycle back into the goat population. Often there is also a focus on preparing and maintaining low-worm risk paddocks for high-risk animals and operations, such as kidding and weaning. While known to be effective (at varying levels), the use of these practices is complex in practical terms, and not always applicable to the various mare segments.

The background knowledge to develop on-farm management plans for internal parasites for each and every producer is full of gaps, poorly supported and not currently being successful.

2. Objectives

At the end of this project the Australian goat industry (through GICA and MLA) have an understanding and appreciation of:

- the current situation faced by goat producers in managing internal parasites in terms of the impacts on production, the practicalities of having limited access to pesticides and the likely future the industry faces.
- The cost, complexities, timelines and product options of undertaking an industry backed program of registration support.

The Australian goat producers will have:

- An opportunity to articulate their issues and concerns around the access to products, effectiveness of their use and how to incorporate best practice pesticide use into their farming activities.
- Additional information and recommended changes to their best practice guide (Going into Goats) based on current knowledge.

Impacts

- Goat producers will have the best information and be able to develop on-farm strategies leading to a more holistic management of internal parasites, reducing input costs and maximising productivity.
- The goat industry will have a reduced potential for the loss of key actives through chemical resistance because of utilisation of best practices.

The project has delivered its objectives in three parts:

- A Technical Review which provides a systematic analysis of the options and issues facing Australian goat producers in relations to the management of internal parasites.
- A Final Report (this document) which outlines the direct and indirect feedback from industry consultation and develops recommendations for the industry in terms of future investment, improved communication and industry lobbying.
- An update to the Module 9- Get Into Goats has been provided along with a presentation for use by Paraboss. The Colere team has also offered Paraboss the opportunity to provide producers with a short series of collaborative webinars.

3. Methodology

This report was designed to combine both the latest technical information, research and practice knowledge with a clear understanding of the current situation being faced by producers. Therefore, the approach taken to prepare the report included both a broad ranging literature and technical review and wide industry consultation.

3.1 Technical Review

Underpinning this report and the analysis provided is a technical review of the issues and challenges of internal parasites in goats undertaken specifically for this project. The approach was as a situational analysis of how the various sectors and regions of the industry are managing internal parasites, the products being used (and their estimated level of efficacy) and the case for new and novel approaches in the future. The review aimed not to reiterate what was available in various guides and through ParaBoss, but to focus on what was missing, where improvements could be made and the knowledge gaps for further investigation. We also needed to understand how and where the various parts of the industry were currently sourcing their knowledge on parasites and their management, how well this information was being adopted and what future channels might be utilised.

The potential for new product development, registration/permits for current actives and evaluation of concepts was viewed through the lens of our experience in the commercialisation and registration of pesticides and animal health products. This provided a practical and realistic context to the likely cost, time and potential for new products in this small but diverse industry.

3.2 Workshops, surveys, and interviews

Colere Group undertook two online workshops as an entry point to broadly consult with what we knew to be a complex industry comprised of several sectors, further broken down by regional and enterprise size differences. The workshops began with brief presentations around the issues and challenges (as originally recognised) then used facilitated breakout groups to discuss and analyse these issues from the perspective of producers, vets, state departmental staff, industry bodies (GICA and Animal Health Australia) and the two rural development corporations (MLA and AgriFutures).

The workshops were followed up by a series of direct interviews with key industry members, goat-focused vets and producers. In addition, we were fortunate to be able to collaborate with two research groups undertaking producer and industry surveys during this time. It is too early to obtain the fully analysed results from these surveys; however, some early results and aggregated commentary has been included in this report.

Of particular value to the process were the longer in-depth interviews with goat specific vets, including Dr Sandra Baxendell, who co-authored the previous 2007 review. The knowledge, networks and commitment of these individuals has been, and will be a key to industry improvement.

4. Results of Industry Consultation and Investigation

This section provides detail of the key issues raised by stakeholders from across the industry (all sectors and regions). Quotes and comments have been aggregated and anonymised and where used directly, are in blue italics.

4.1 Current Product Use

There are only six active ingredients for internal parasiticides registered for use in goats in Australia (compared to fifteen for sheep), and no new active has been registered for goats since 1996. Of those registered actives, significant resistance has been documented against all apart from triclabendazole, so it is not surprising that in producer and stakeholder surveys and interviews the majority report having to use sheep registered anthelmintics off-label to ensure effective treatment of their goats.

Internal parasiticides APVMA	Goats	Sheep
Total registered products	17	391
Active ingredients	6	15

(PubChris Mar2023)

The scope of actives reportedly used in the workshops and interviews reflected the issues the sector faces: rangeland goats, if treated, were often treated with pour-on anthelmintics, due to reluctance to orally drench given the associated animal management issues; smaller producers prioritised anything available in smaller pack sizes, or products recommended by the local rural reseller, while a minority undertook testing and appropriate anthelmintic selection and use. A small number of producers recognised the issues and sought advice from their vet.

This struggle to find effective products from within the limited range of registered internal parasiticides available for goats has been an ever-present struggle for producers for over a decade-

In a 2014 survey of 88 Australian goat producers 73% considered GINs had caused production losses or health impacts for their goats during the 5 years prior to the survey. Over 80% reported that there were inadequate number of anthelmintics registered for goats and of the producers who used an anthelmintic during the survey period, close to 70% had used a treatment not registered for use in goats.

Product selection

Producers have difficulty negotiating the information supplied to make a decision on the right product to use. There are many complexities, however the ParaBoss Drench Decision Guide is not working for most. Legally it can't recommend products that are not registered for goats, yet these are what the majority of producers are likely to be using. Therefore, producers are forced to go to vets for off-label prescription and advice, or to use products off-label without veterinary prescription.

The current ParaBoss tool is a linear decision tree and incorporate limited amount of additional information that may impact decisions (such as size of operation), it does not provide an opportunity to input multiple fields before directing the user to either doing faecal egg counts or selecting a drench. The drench active recommended is then provided with a disclaimer suggesting (in most cases) that there will be resistance. The result is producers making their own decisions on drench selection and dose rate without the access to the latest best-practice knowledge. This may work for larger and well-informed producers but for smaller and less experienced and informed producers it is only of limited help.

For parasiticides that are used off-label, there is a great risk of subtherapeutic doses being administered. There is very little published information for prescribing vets to draw on about pharmacological profile in goats of any anthelmintic discovered in the last 20 years, and for the producers who do not or cannot go to a vet, they must rely on sources such as chatboards, social media and word of mouth, or alternatively give the (usually) subtherapeutic label dose indicated for sheep, further exacerbating resistance development¹.

"The product selected and rates used is largely a decision being made by producers, without direct advice...therefore some are doing this well, but many are not."

4.2 Vet access and vet knowledge

The lack of registered products requires producers to rely heavily on the use of off-label prescription, which must be used under vet supervision, if they hope to remain within the legal framework. However, our consultation with industry raised issues around access to vets with goat medicine knowledge, as well a range of state-based issues that limited accessibility.

The level of goat medicine knowledge held by vets practicing in urban, peri-urban and rural regions was seen to be generally poor. The large-animal practitioners (those looking after horses, cattle and sheep) often saw goats as akin to sheep, and those closer urban areas (many small producers are in peri-urban regions) saw them as livestock and unfamiliar compared to the companion animals they usually treat. Neither, in many cases, was willing to provide off-label recommendations due to the perceived risks of WHP and product sensitivities. In part this is due to lack of readily accessible information on which to base their recommendations, concern about legal liability in the absence of

¹ Around 50% of respondents to a goat survey in 2019 indicated using an off-label parasiticide, at the sheep label dose. (Brunt et al, 2019)

readily available scientific information, and sometimes producer unwillingness to pay for a consultation and the veterinarian's professional time.

The producer surveys repeatedly returned to the issue of access to vets willing to prescribe, with knowledge of goat medicine, in their area or even state.

"...can we influence training outcomes for vets that build capacity in goats?"

"Calling a vet to get an off label (recommendation) can be a mixed bag, some just don't want to take any risks and effectively fob you off."

"As a vet I'll verbally discuss options but won't write a prescription as I can't give a WHP"

Results from an unpublished goat producer survey (with majority smaller producers) into Barbers Pole Worm management indicate that only 45% of producers sought veterinary advice about anthelmintics (Pers Comm Dr Marisa Wood 2023). While it is unclear whether this was due to access or by choice, without appropriate information on dose and withholding period this indicates the risks around subtherapeutic dosing, safe use of multiple anthelmintics and meat and milk residues.

The review makes a series of short to medium term recommendations around putting information into vet's hands to enable them to be informed and upskilled with the aim of improving by producers to off-label anthelmintics. This is detailed in section 5. 3 below.

Access to vets was to some degree exacerbated by state-based prescriber restrictions. For example, in some states, such as Queensland, for a vet to prescribe to a producer, additionally to the national requirements for a bona fide vet- client relationship, the vet must also have seen the animals within the last 12 months. Qld does allow for telemedicine services, in part to address the issue of vast distances between producers and vets (telemed is not available in other states), however vets must offer this service and practice from a premises that has been approved by the Veterinary Surgeon Board of Qld and be located in Qld.

The result of these requirements is that in addition to the issue of limited number of vets with goat experience in large states such as Qld, there is no potential for a vet from outside Qld to prescribe to a Qld producer. It is noted that similar state restrictions are present in other states, and vets operating in border areas are required to be registered with the veterinary surgeon boards in both states, however, do not need to have registered practices in each state.

"As a Qld Vet, I need to get out on the road several time a year to visit producers so I can rightfully claim that I have seen their animals. I can't really charge them for this as we may have had several video chats through the year where I effectively saw everything anyway...the rules need to catch up with the realities of what we face, or producers will just do their own thing and consult Dr Google."

4.3 Producer knowledge

The levels of knowledge and understanding around internal parasites, the best practice management approaches and on-farm strategies for animal health and productivity are as diverse as the industry.

In general, the larger and higher value producers (often the fibre and dairy sectors) have sought knowledge and developed strategies that have helped them maintain moderate to good health and productivity. Improvement in these enterprises is still possible (and desirable), in particular knowledge about recent and emerging chemicals and parasite management practices specific to

goats. As mentioned previously, much of this is due entirely to the inability for information/recommendations to be openly and legally shared, as well as the heavy dependence in available information being based on data in sheep. Most have a good grasp of how to use concepts such as quarantining and routine monitoring for evidence of parasitism.

At either end of the industry, the largest rangeland producers and smaller hobbyists have the least knowledge, and one could argue the least range of applicable tools for management. Existing information tools such as WormBoss are not sufficiently well used, with 45% of goat producers surveyed in 2023 stated that they had not used any worm control methods sourced from WormBoss (Pers Comm Dr Marissa Wood 2023). This compares to sheep industry, where in a 2018 survey over 60% sheep farmers reported visiting WormBoss (Colvin et al 2020). There are many anecdotal reports of smaller producers using social media for information because existing channels are more difficult to access/ understand/utilise than social media, and of producers underestimating worm issues because of this lack of cut through in extension information. The review team sighted numerous examples of completely illegal, useless or even dangerous recommendations through Facebook groups, and the simple fact that producers are asking for help in these channels is a clear indication that the current information channels are not best fit for purpose.

“...continued residue detection is going to cause market problems, we are going to have a big issue at some point, especially if they begin testing the domestic supply chains.”

“We need improved mechanisms for the dissemination of information to producers. Workshops/ online webinars etc. This seems to be happening across other aspects of the industry.”

“Producers in this industry are on our own, so need access to information in a different way from sheep/cattle (who have access to multi-generational farming & major industries). This includes info on many basic things vets would ordinarily do, but don't do in this industry.”

This is an ongoing issue and aligns with other surveys, Brunt et al (2019) found that almost half the respondents stated that there was inadequate information available to support effective internal parasite control, and this review makes a series of recommendations around goat industry-specific information sources, discussed in section 5.3 below.

Worm burden monitoring: Faecal Egg Counts and Resistance testing

FEC and FECRT have been around for decades, require training and are labour intensive, yet are to this day the most effective test to determine herd and individual worm burden and to estimate anthelmintic resistance levels. With resistance ever rising, monitoring parasite burden is increasingly important. Surveys of goat and sheep producers are roughly in line, showing that the majority have used FEC at least once (66% goats), but fewer report using FEC routinely and as part of the decision process for treatment (50% goats) (40% -54%: sheep)² report using FEC routinely³, indicating underutilisation of FEC and FECRT is a serious problem for the goat industry, despite the obvious value to producers. The best sheep and goat producers are using FECs on a regular basis to guide their decisions and even testing individuals selected to better understand flock dynamics as a basis for management practices such as refugia and control deworming. Historically, access and the cost of testing has limited goat producers' use of FEC and resistance testing via FECRT, however,

² Noting that the wording of the questions across the surveys relating to FEC/ WEC differed between the studies making it difficult to undertake a more direct comparison of the results.

³ Refer to section 7.2 of the Literature Review document for detail and sources

advances within the testing landscape should make laboratory-based testing easier and cheaper in the future. There is also potential future in yard-side testing.

A key complaint from producers, particularly those in remote areas, is the turn-around times required for lab-based testing, with factors such as speed of postal services and loss of local and regional laboratories raised in the producer workshop and discussions. Small producers are also disadvantaged by the cost-benefit of testing as they cannot spread the cost across a flock or utilise pasture management practices indicated by high FEC results, such as such as quarantining and spelling.

Taken together this indicates the problems across both sheep and goat production industries with promoting parasite management approaches based on frequent FEC testing, when FEC monitoring of any level is only undertaken by half, or at best, two thirds of the wider producer cohort⁴.

“Access to FEC/WEC in remote areas- very difficult due to freight/postage pathways to get samples to lab within 5 days.”

Producers want to do egg counts themselves. Where and how do they get training and resources.”

“Many rural resellers are offering worm egg counts - e.g. Elders using parasight etc -Possible opportunities to bring base level understanding up through awareness?”

This report has reviewed the emerging advances in lab technologies and the recommendations in relation to this gap are discussed in 5.5 below.

On-Farm Strategic and Integrated Management

There are a minority of producers across the industry who have taken the time to develop a farm plan that utilises all of the tools available to the scale and type of enterprise they operate. Many have developed strong relationships with specialist goat vets or spent the time and energy to inform themselves about the various parasite issues endemic to their area and built according to strategies. These producers report a level of ongoing success, as evidenced by low FEC results and in some cases are still able to utilise older active combinations. The fact that this group has representatives across most sectors and regions, gives this review credible evidence that the industry can successfully manage these issues.

“We need to understand more about pasture species that could reduce worm burden in goats.”

5. Strategies for a better future

Readers of this report would not be surprised to hear that there is no single, simple answer to internal parasites in the Australian goat industry. There are no new products or practices on the near horizon that will (alone) make a significant difference, and therefore we need to consider how we can better utilise the tools at hand and use the limited industry funding to best possible effect.

5.1 Registration of a new chemical anthelmintic product for Goats

The issue of registering new anthelmintics for goats is problematic, even considering those that have been registered for use in other species for some time. The technical review details the difficulties and costs to register new anthelmintics in a new species, and the reluctance of big pharmaceutical companies to register a new active in goats (a species perceived as exacerbating resistance

⁴ Variation between states and producers

development). In addition, the cost and effort of registering a specific active need to be weighed against the speed of resistance development, and the risk that product, if and when it obtains registered label claim, may already have serious resistance levels, significantly depleting the value of this investment. Section 4.3 of the Technical Review gives an overview of resistance across the range of anthelmintics under consideration.

Furthermore, the APVMA data protection system ensures that the data required for them to evaluate a new product, or a label claim to a new species, can only be accessed with the approval of the original registrant (the pharmaceutical company); and data protection usually expires 10 years from registration. Therefore, any decision on which active to pursue is closely linked with finding a registrant/ manufacturer willing to partner with a label extension to goats.

The results of the efficacy and residues studies from Doyle (2021), in light of these factors, draw the following conclusions: Startect (Zoetis) is a new registration for the large multinational, and they will be highly unlikely to approve the extension of use to goats in the next 10 years. Zolvix (Monepantel; Elanco) is similarly a new active for a large multinational, however it is reaching the end of its data protection. In addition, monepantel has an EU published MRL, which may help in APVMA determination of a MRL and WHP for goats. There is some indication of emerging resistance in sheep already, although possibly less than for moxidectin. Moxidectin (Cydectin) is available as a generic, however resistance in the field has already been reported.

Should registration be pursued, the recommended path is to apply first for a minor use permit then transition to full registration. As detailed in section 10.3 of the technical report, this gives the shortest timeline, earliest access to an active and lowest cost, which nonetheless starts at 2-5 years and AUD\$350-450,000 from date submission lodged (this is an estimate only as it is very difficult to predict in advance the studies required).

Section 5.3 addresses alternatives to a new product registration.

5.2 Alternatives parasite control options

With a shrinking pipeline of new actives alternatives to traditional drenches will need to play a large part in the future management of internal parasites for all animal production areas. In addition, the use of these products (as well as management practices) when combined with judicious use of drenches will hopefully extend the useful life of all products.

Copper oxide wire particle (COWP) bolus products:

COWP bolus products are already registered for use in sheep in Australia, data on overseas use in goats exists, and they are currently being used by some local goat producers off-label. The mode of action is discussed in **Section 6.2.3** of the technical review, and their activity appears to provide a useful break in *H. contortus* cycles, reducing adult numbers in the animal, and the volume of eggs shed onto pasture. There are however, potential animal safety issues with COWP and therefore a need for more data in goats under Australian conditions, to provide improved recommendations for COWP use.

In the short- and medium-term it would be useful to survey Australian goat producers using COWP to collect the field-level user-experiences of COWP; including dose rates being used and perceptions of effectiveness. This information can then feed forward to sponsor a study into COWP in goats under common Australian grazing conditions, confirming dose rate and safety under extended use

patterns. This could be an industry-led undertaking, or in conjunction with a COWP manufacturer, with a view for them to make a future APVMA label claim extension.

In particular, the industry needs to clarify the risk of toxicosis been exacerbated by grazing plants with hepatotoxins, such as Patterson's curse.

Vaccines

The future for vaccines for use to reduce parasite burdens in animals is more positive than it has previously been, with recent advances in fields such as genomics, RNAi antigen validation modalities, adjuvant developments and broader host-parasite immunological knowledge, as summarised in the MLA- supported review by Britton et al (2020). Vaccines are the most convenient way to cope with a future less reliant on anthelmintics- they have zero residue issues, are generally safe to use in young animals, have medium to long durations of immunity, and can be used concurrently with other methodologies. Additionally, any vaccine developed for sheep will address internal parasites found in goats.

None the less it is most likely that vaccines will provide at best moderate efficacy at a herd level and will therefore need to remain part of a suite of approaches to parasite management, in combination with judicious parasiticide use. Section 4.1 of the Technical Review details the role of vaccines in parasite control and the potential emerging science.

However, at this point in time, Britton et al's review (2020) could not point to a successful vaccine candidate on the near horizon, so a longer wait is needed. Currently there is only one vaccine against gastrointestinal parasites currently available. Barbervax (against *H. contortus*; Moredun Laboratories) is registered in sheep, has been shown to be safe in goats but with evidence of variable efficacy in goats (Smith 2016). Producer surveys found that it is being used in high barbers-pole risk areas.

In the short term, a survey of producers regarding perceived Barbervax efficacy, and user experience information (what is driving producers to use, and what is preventing other producers from not using) would help to understand the real value of the product in the goat industry and perhaps identify its best fit. There is also value in investigating Smith's (2016) study data further for insight into the variability at one of the study sites and the potential to undertake further work in goats, in collaboration with the registrant, Moredun. The first step would be to approach Moredun for access to the raw data from the 2016 study.

There is a potential path forward, if the data is strong enough, and it is deemed of value to the industry, for a collaborative approach to APVMA for a minor use permit for Barbervax. Data requirements for a minor use permit of a vaccine are significantly lower than for an anthelmintic.

Condensed Tannins (CTs):

Plant based CTs show some promise as chemical-free, feed additives to reduce worm survival in the intestinal tract, reducing pasture contamination. CTs have some impact on all GIT roundworms, however efficacy is incomplete and CTs must always be used as part of a broader suite of interventions. The review also discusses evidence for synergy between CT and COWP use, which would benefit with further exploration within the Australian goat production context.

The wider ruminant industry should support further research into Australian sources of CTs, both introduced and native, and impact on worm egg excretion under Australian field conditions would help understand this within Australian grazing conditions, for goats, sheep and cattle.

For both the intensive production parts of the goat industry, and small producers (with limited grazing opportunity) there is a compelling case for the development of a CT feed additive for inclusion in daily rations. There are a range of byproduct, natural and cost-effective sources of CT materials that could be considered.

Pasture burden targets:

Duddingtonia flagrans

The pasture phase of the internal parasites offers an alternative focus point in their lifecycle to break cycles or reduce numbers. In addition, impacts here can dramatically reduce the populations of parasites that have had exposure (and survived) specific anthelmintic applications, reducing potential resistance build up. Microbes that specifically predate or are pathogens of nematodes are discussed in section 6.1.3 of the literature review as possible alternatives for the management of parasites during their pasture phase.

As a fungal killer of nematode larvae in pasture, *Duddingtonia flagrans* presents as a useful tool to reduce pasture contamination. Bioworma® (*Duddingtonia flagrans*, International Animal Health) is administered directly to animals in their feed, therefore utilising them effectively as a vehicle to spread the fungi onto pasture, to directly control the larvae as they emerge. It is known to be effective in times of high egg shedding and when conditions for parasite larvae are ideal. The requirement for daily (or at least very regular) administration, the cost and the palatability of the formulation has restricted goat producers use to date. The safety of the product (for user and animal), compatibility with other management approaches and fit for smaller producers makes this product a priority for the industry.

To build the use potential for *Duddingtonia flagrans* based products we recommend:

- Research into further options for premix style sources of *Duddingtonia*, to blended goat-friendly feed supplements, and/or alternative delivery modalities such as ruminal boluses, pelletised palatable formulations, and combination with phytoactives such as condensed plant tannins.
- The use of RFID supported supplementary feeding technology may be a way to take the use of these products to the more extensive animal systems. The ability to autonomously and individually dose animals daily in the field would extend the value products such as Bioworma to a much wider use group. This would not require any changes to the APVMA approved label or registration as long as the dose rate of 1 g/kg body weight is met.
- The specific strain (*D flagrans* strain IAH 1297) is the current one registered and it was developed by the CSIRO prior to 2002. To support the longevity of the concept we suggest investment into the development of alternative isolates of *D. flagrans*, either drawing on previous CSIRO work and/ or including locally sourced isolates from goat farmed areas. The APVMA requirements for these bio-pasture products are lesser than parasiticides as there is no effect in animals and efficacy is evaluated in the pasture, so much of the registration could be undertaken by argument and published papers. Co-development for sheep and goats would be the preferred path.

Bacillus thuringiensis (Bt)

The potential of *Bacillus thuringiensis* (Bt) crystal protein products is a promising development for *H. contortus* management in ruminants. While the work of Sanders et al (2020) was exploratory rather than developmental, the results (reductions in faecal egg counts of 90%, parasite burdens 72% and specific impact on female parasites with 96% reduction) is compelling. The breakthrough in oral formulation may be what is needed to take a well understood and widely registered active (Bt Cry5B) through to this new use. Obviously, this opportunity is far broader than goats and Australia, and a business case would need to be developed to better understand the FTO and development pathway.

Chryseobacterium

International research into species of bacteria belonging to the *Chryseobacterium* genus (golden bacteria) have been evaluated as potential options for field management. Unfortunately, to develop one of these products for Australia, it is likely that an indigenous version of the species would need to be found to address quarantine and import legislation for biological material, wherein importation and release of non-native organisms is very rarely allowed.

The reviewers are also sceptical of the potential of these products in our farming systems due to the requirement to spray them on a regular basis over the entire pasture. If a formulation that was capable of passing the bacteria through the animal was developed this might be an option.

Novel concepts

The Technical Review identifies early work being undertaken in the field of RNA interference, perhaps the most exciting current area of new pesticide development. While there doesn't appear to be any groups directly working in this field in regard to internal parasites in ruminants, there is evidence to suggest that the pathway is worth exploring. There are several highly experienced RNAi research groups here in Australia and there is potential for the Red Meat industry to partner with one of these to develop a proof of concept.

5.3 Improved vet access and utilisation

More access to information is critical to enable improved veterinary advice and best product and best practice utilisation by producers. In the absence of new registrations, the only access to the most efficacious anthelmintics is via off-label use and the only legal access point is via veterinary prescription and advice.

There is a paucity of quality data around newer anthelmintic use in goats globally and without it vets have nothing of scientific value with which to base their estimates of dose, safety and WHP. Even vets that frequently treat goats put their registration on the line when prescribing off-label in the absence of data. Providing readily accessible information and data around anthelmintic use in goats can provide knowledge security when vets prescribe, and producers use anthelmintics off label.

Studies such as undertaken by Doyle (2021) improve understanding of the efficacy, pharmacokinetic and residue depletion of the selected anthelmintics and can provide a wealth of information to assist vets and producers. Doyle's study indicated a series of important findings:

- Confirming that goats under Australian grazing conditions metabolise anthelmintics around 1 to 1.5x faster than sheep.
- Proving that transdermal administration of sheep and cattle formulations cannot be relied on for goats.

- Showing that long acting injectable moxidectin doesn't peak well enough to work in goats.
- Identifying residue depletion curves and showing that the tested anthelmintics depleted within a similar WHP to sheep, despite the higher dose rate.
- Indicating that 1.5x sheep dose is safe to use in goats.

In the USA, with similar limitations on registered and effective anthelmintics for goats, producers and vet have access to FARAD⁵, as well as industry-led organisations such as the American Consortium for Small Ruminant Parasite Control⁶, The American Association of Small Ruminant Practitioners⁷ amongst others, enabling information access to vets and producers.

In the short to medium term, putting information into vet's hands to enable them to be informed and upskilled is the most effective way of improving access to off-label anthelmintics. There are limited goat specialist vets in Australia, so there is a need to provide easy to use information for generalist vets so they can still prescribe safely and in confidence. The review team make the following suggestions:

- MLA and AHA to support a veterinary level goat medicine portal⁸, hosting up to date information about diseases in goats, including parasitism. Highlight on drench selection and what does not work in goats, anthelmintic dose rates, and data indicating withholding periods and linked to all published references. The aim being facilitating vets upskilling in goat medicine and providing fast and accessible information for off-label prescribing and guidance. Ideally this could be done in close collaboration with the Sheep, Camelid and Goat Veterinarians subgroup of the Australian Veterinary Association:
<https://www.ava.com.au/about-us/ava-groups/sheep-camelid-goat/>
- A vet resource of this type should be introduced to vet students and new vets through university vet school connections.
- Develop a very simple one-page style goat anthelmintic use 'information pack': a fast-read dose rate, safety and WHP cheat-sheet, accessible online, with a QR code or on paper.
- In the longer term, push for development of a system such as FARAD (USA) which hosts WHP information and advice for off label use in all food producing species, to help vets prescribe off-label with safety and knowledge. Such a system should ideally have the capacity for vets to ask for advice on WHPs based on dose rate and species. This could be hosted by an independent entity, such as AHA.
- Publish the results of the study undertaken by Doyle (2021) in a peer reviewed journal, so that summaries of such data can then be reported in secondary sources that are more accessible to vets and producers, such as the 'information pack' described above. The study undertakes off-label use in a non-registered species, and it reveals some parasiticides in a poor light, such as transdermal penetration, long-acting formulations and local resistance

⁵ <http://www.farad.org/>

⁶ <https://www.wormx.info/>

⁷ <https://www.aasrp.org/>

⁸ Example of USA sites include Goatworld: www.goatworld.com, Pennsylvania State University Extension Services: Goat Health and Care website: <https://extension.psu.edu/animals-and-livestock/goats/health-and-care>; and American Association of Small Ruminant Practitioners resources: <https://www.aasrp.org/Main/Main/Resources/AASRP-Species-Resources-Files.aspx?hkey=8ab0b513-a732-4b2e-847a-c7318264006b>

issues, so publishing in a journal addresses any legal concerns that may arise around disseminating the results more widely.

- Undertake a similar study to Doyle 2021 in another 5-10 years, with a newer, more contemporary selection of anthelmintics, including co-administration of 2 or 3 anthelmintics to gather more information about the safety, residue depletion and efficacy as discussed in section 10.2 of the literature review.

5.4 Improved Producer Knowledge: Tailored communication and extension

The majority of producers want more information to help them make the best decisions to manage parasites on farm. Difficulties in selection of best parasiticide and dose was repeatedly raised in consultations. WormBoss as a tool is constrained by its focus on major species, sheep and cattle, and by its complexity for casual and hobby users. Working to raise the lowest level of producer knowledge with a targeted approach to small and hobby producers will have the most significant impact. Decades ago, small producers could have conversations with Regional Department Vets, Agronomists, RLPP board vets to gain correct and current information tailored to their level, but these resources are scarce now.

Via ParaBoss

ParaBoss is seen by most who visit as a trusted source of information, therefore should be supported to maintain relevance. The difficult balance is between providing information for a diverse range of technical levels, as well as the industry segments.

- Develop a simple to use decision tree specific for goat producers, taking into consideration all industry segments and producer sizes.
- This decision tree could even outcome as a printable downloadable summary, which could include instructions for approaching a vet for off-label prescription, including recommended dose rates and estimated withholding periods for anthelmintics (with appropriate legal consideration), for producers to use when talking with their vets.
- Similarly, an easy-to-use goat specific decision tree for pasture management, to better use the information within Paraboss. While there are significant volumes of information there, it is difficult to navigate and even more difficult for a producer trying to formulate a plan.
- For time poor producers, the complexity of working through all of the range of variables for each grazing block throughout the year this is not simple. There is therefore an opportunity for decision making tool that helps calculate the likely pasture parasite load across the wide range of combinations, to help make decisions on rotation speed and grazing intensity.

Social Media

The role of social media for all levels and segments of the industry cannot be ignored. The rapid responsiveness, often generous (if misguided) support and general accessibility is making forums like Goats Australia (a Facebook group with 6.9K followers) a first stop for many.

- Go where these producers are searching for information, such as Facebook. An industry hosted Facebook page could be a readily accessible site for information targeted to pet, hobby and small farmers. Potentially this site could be where users could ask for advice and connect with more informed producers or content moderators, and to provide a

targeted friendly and accessible focus on parasite management and integrated pasture management. Moderation would be required.

- Such online/ remote service could potentially be legally provided across state borders if undertaken specifically without providing veterinary advice (such as off-label recommendations or medical advice), and specifically not fall under the relevant veterinary surgeons act and associated legislation.

There is now a general acceptance that media such as short-form instructional videos do not need to be highly or professionally edited (driven by a plethora of Apps and content providers). This provides an opportunity for low-cost production (but still highly technically correct) content to be delivered in a format that is easier to access and relate to instantly by an audience comfortable with this media.

- A good example of this is replacing a written explanation of how to correctly use drenching guns (provided both in GIG Module 9 and ParaBoss) with a 3-5min video with text overlay.

Small Farm Plans

Semi-tailored plans seem to be an ideal way of assisting smaller producers with sensible and cost-effective management strategies.

- Dr Sandra Baxendell undertakes individual worm plans for her small and hobby producer clients, many connected through social media. Consider the best methodology whereby Industry could provide an incentive level support, such as a small voucher to entice small and hobby producers to have an online/ remote individual worm plan.

5.5 Better testing for parasite burdens: whys and hows

Access to rapid easy and cheap quantitative faecal egg testing is critical in understanding and managing gastrointestinal parasite burdens at group and individual level. Combined with the potential to differentiate between *Haemonchus* and other gut round worms, producers can evaluate the need for parasiticide treatment, refine treatment regimen in line with weather conditions, and obtain a rough evaluation of drench efficacy.

With the right support the industry could move closer to a best-practice position where FEC testing becomes a routine operation occurring before any drench decision is made, after a drench is undertaken and to animal and pasture contamination across the seasons. For this to occur we believe the following needs to be considered:

- Better producer education to inform producers about ready availability of FEC and PCR based testing- the how and the why. While there is some good information already available, it does not clearly differentiate between the types of tests, their varying costs and benefits and how to select the best option for the circumstances.
- Investigate opportunities for the industry to support access to tests such the lab based rapid multiplexed roundworm test differentiating between *Haemonchus contortus* and other gastrointestinal nematodes used by Joan Lloyd consulting.
- FEC training events specific for goat producers: in person, remote and recorded for catchup.
- Provide easier access to up-to-date worm testing options specific for goats, regions and production, plugging the gaps currently existing in Wormboss: from how to do a FEC on farm, to use of external lab providers, through to Elders' Parasite®. This dovetails with the recommendations above to improve producer knowledge. Work across modes: in person, remote and recorded for catchup.

- In conjunction with the sheep industry, prioritise industry investment for development of low-cost semi-quantitative molecular assay for ruminal gastrointestinal parasites. This might be something like a pen-side or goat-side lateral flow test that could provide the above information cheaply and rapidly, to goat and sheep producers alike. In general fast and cheap tests are less accurate than laboratory testing, however for worm burden evaluation that is regularly repeated across the year, it is clear that high accuracy is less important than a lower accuracy test that is easy and cheap to use and will therefore be used more frequently across the year.

6. External communication and lobbying

Like most smaller industries, goats are caught in the ethical and legal bind in regard to registered products. Industries struggle to communicate at regulator and legislator level, the difficulties faced by producers to operate legally and ethically, while still needing access to medicines and anthelmintics that work, and which multinational pharmaceutical companies are unwilling to register for use in goats. While the minor permit system is designed to help alleviate this bind, the companies still need to comply and, in most cases, significant investment is still needed. While we have recommended a possible path in terms of new permits, we also recommend:

- Pushing for development of a system such as FARAD (USA) where WHP information and advice for off label use in all food producing species is hosted by an independent entity, such as AHA. This benefits the wider ruminant production industries.
- Promotion of discussions at legislator level for wider ability for vets to do teleconsulting around Australia, in line with the medical profession. This benefits all remote and regional animal producers.

7. Conclusion

In summary, internal parasite management currently requires significant producer energy and resources across the goat industry and there is no single solution that will change this. Parasite management is a lifelong concern for farmed goats, and there will never be a single chemical solution to deal with parasites. This review offers medium to longer term recommendations around registration of a new goat use claim for an existing registered anthelmintic.

Equally, the review details recommendations for more accessible and short- to medium- term non-chemical advancements, such as better knowledge around *Haemonchus contortus* vaccine (Barbervax) and Copper oxide wire particle use (COPW), as well as pasture worm burden reduction through biological products such as *Duddingtonia flagrans* (Bioworma). Promoting development and update of emerging and on-the-horizon changes to FEC tests are also proposed- without easy fast and cheap FEC tests to enable monitoring of animal and pasture parasite burden, many producers will feel they have few choices but to keep returning to old and inefficient parasiticides.

In tandem, with this, the review points to a series of achievable recommendations that can make a significant change in the short to medium term around information generation and dissemination to goat producers and vets; working with available tools such as social media and online decision trees for producers and greater access to dose, safety and WHP advice to vets to facilitate confidence in off-label prescribing.

Longer term changes such as structural changes to the chemical regulatory environment in Australia and the veterinary practitioner legislation between states are also detailed, as well as longer term

scientific advances, primarily led for sheep and cattle parasite control, but that can one day positively impact on goat parasite management.

7.1 Key findings

There are significant structural constraints limiting registered products available for use in goats (anthelmintics, vaccines and nonchemical parasite treatments. These constraints are difficult to influence and unlikely to change in the foreseeable future. The APVMA is legislatively bound and unlikely reduce the registration requirements to make it easier for a small animal production industry, and pharmaceutical companies find it difficult to justify the high regulatory spends required to register a product in this minor species, or to put any risk on returns from any new anthelmintic molecules. Similar issues are faced by goat producers in USA and EU.

There are no new magic-bullet parasiticides on the visible horizon, and if they do come they are unlikely, as usual, to be registered in goats. In the meantime, parasite resistance to older anthelmintics is widespread, and is increasingly emerging in the newer anthelmintics registered in the last 20 years.

The only viable approach in the short term to operating within these constraints is to work within the opening provided by the legal rights of vets to prescribe off-label products that aren't otherwise registered in goats. This is the only legal path to enable producers access to APVMA registered chemical and nonchemical products needed to keep animal and pasture parasite burdens under control. This review makes a series of recommendations to facilitate this, primarily via a strong focus on making more information available to vets and producers and putting easy-to-access information where vets and producers can find and use it. To an extent this also requires better educating producers to then help inform vets, especially generalist vets who don't have sufficient goat experience to feel comfortable providing advice.

Hand in hand with this approach is to intermittently generate contemporary data in goats under Australian conditions, where otherwise this information would not be generated: dose rate, efficacy, and residue studies on recent anthelmintics in Australian grazed goats, to provide vets and producers with data to prescribe and use safely and effectively and address the industry wide risk of residues in goat products.

The review considers the advantages and disadvantages of pursuing a new anthelmintic registration. This is a resource-heavy project and needs to be considered seriously before proceeding, especially if it would result in draining all resources from the other recommendations.

There are several scientific advances in the pipeline to provide hope that in the future there will be effective vaccines against internal parasites, more accessible tests (such as rapid yard-side parasite testing), and better tools to manage larval parasite burdens in the pasture. This future is not close, but it must be actively targeted.

7.2 Benefits to industry

Producer consultation shows that the goat industry is broad and diverse, containing many good operators using best practice at the top end, but a long tail of producers who struggle to find sufficient information and assistance about best practice parasite management.

The literature review details how goats are different to sheep when it comes to anthelmintics and the findings of this report prioritise more access to goat-specific information about anthelmintic use,

leading to more informed use of anthelmintics, resulting in better practice, safer and more sustainable anthelmintic use. With this comes the parallel aim of reducing production losses from parasitism and better practice reducing the risk of residue detection in goat products.

More sustainable anthelmintic use and best practice parasite control in goats further benefits the sheep industry by addressing the risk of resistant population development in goats transferring to sheep.

8. Future research and recommendations

1. Recommendations benefiting goats and sheep: These species share the same range of gastrointestinal parasites, so many of these insights and findings apply to both industries. It is most likely that any breakthrough will be via sheep based research, but will equally assist both industries:
 - Prioritise industry funding for gastrointestinal nematode vaccine development. Ensure goats are part of the development plan.
 - Prioritise industry funding for development of faster cheaper and easier testing for parasite burdens with ultimate focus on a cheap, easy to use on-farm and yard-side tests.
 - Investigate a next stage *Duddingtonia flagrans* nematocidal pasture product to address current issues of cost and palatability, as well as easier delivery modalities, including delayed release formulations.
 - Prioritise research into other biological nematocides such as *Bacillus thuringiensis* (Bt) products and other soil bacteria, either via animal delivery or direct pasture application.
 - Prioritise research into feeding of condensed tannins (CTs) / feed supplemented with CTs in sheep and goats under Australian grazing conditions, using accessible plant byproduct/ waste streams. Investigate how CTs can be combined with COPW and/or other biological nematocidal products for multi-action.
 - Lobby for a national data and support system similar to the USA's FARAD system; to give vets and producers access to residue depletion data, better calculations of WHPs and support for WHP queries for off-label use in all red meat species.
2. The following recommendations apply specifically to goats and fill knowledge gaps, leading to better and safer use of products and wider uptake. Such an outcome also benefits sheep, as better control of internal parasites in pastured goats reduces perceived or real risks around anthelmintic resistance development in goat parasites spreading to sheep and cattle.
 - Obtain more data about use of COPW in goats on Australian pastures to better understand the safety profile of the product. COPW may offer a useful break in *Haemonchus contortus* development and pasture burden.
 - Obtain more data around use of Barbervax in Australian goat populations. Work with manufacturer, Moredun, to review data from goat studies they commissioned, possibly leading to a co-produced label claim for minor species.
 - Improve producer access to existing technology; lab based rapid multiplexed roundworm test differentiating between *Haemonchus contortus* and other gastrointestinal roundworms.
 - Every 5 years commission an anthelmintic study in goats, to build a data base of efficacy, safety and residue depletion of present and upcoming anthelmintics that aren't registered but are being used in goats. Publish all studies for open access so vets and producers have access to the information.
 - Improve access to goat-specific information on parasite control to producers at all levels in the industry through a range of approaches discussed.

- Develop a Vet information hub for goat medicine, with a focus on parasite control.
- Lobby for updates to state based prescribing restrictions to enable e-consultations and cross border prescribing.

9. References

- Britton, C., Emery, D.L., McNeilly, T.N., Nisbet, A.J., Stear, M.J., 2020. The potential for vaccines against scour worms of small ruminants. *Int. J. Parasitol.* 50, 533–553.
<https://doi.org/10.1016/j.ijpara.2020.04.003>
- Brunt, L.M., Rast, L., Hernandez-Jover, M., Brockwell, Y.M. and Woodgate, R.G., 2019. A producer survey of knowledge and practises on gastrointestinal nematode control within the Australian goat industry. *Veterinary Parasitology: Regional Studies and Reports*, 18, p.100325.
- Colvin, A.F., Reeve, I., Peachey, B. and Walkden-Brown, S.W., 2020. Benchmarking Australian sheep parasite control practices: a national online survey. *Animal Production Science*, 61(3), pp.237-245.
- Doyle, E., 2021. Sustainable internal parasite control in goats: Effective and safe anthelmintic use (No. B.GOA.1907). Meat & Livestock Australia Limited.
- Sanders, J., Xie, Y., Gazzola, D., Li, H., Abraham, A., Flanagan, K., Rus, F., Miller, M., Hu, Y., Guynn, S. and Draper, A., 2020. A new paraprobiotic-based treatment for control of *Haemonchus contortus* in sheep. *International Journal for Parasitology: Drugs and Drug Resistance*, 14, pp.230-236.