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Original article

A producer survey of knowledge and practises on gastrointestinal nematode control within the Australian goat industry

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ABSTRACT

Gastrointestinal nematodes (GINs) have been identified in Australia as a major problem in goat production, with few anthelmintics registered for use in goats. Therefore, anecdotally many producers use anthelmintics that have not been registered for goats. Using unregistered products could increase selection pressure for anthelmintic resistance as well as safety and/or meat or milk chemical residues of products from treated goats. This producer survey was conducted in 2014 to establish Australian goat producer knowledge, perception and practises of GIN treatment and control.

Eighty-eight producers responded to the survey. Of these respondents, 90% thought that GINs were a problem for the Australian goat industry, and 73% considered GINs had caused production losses or health impacts for their goats during the 5 years prior to the survey. With regard to anthelmintic resistance, 7% believed that anthelmintic resistance was not a problem at all, 93% acknowledged anthelmintic resistance was a problem in Australian goats herds, with 25% of these reporting their properties as being affected.

The majority (81%) of respondents believed the number of anthelmintics registered for goats was inadequate for effective GIN control. Of the 85% of producers who used an anthelmintic during the survey period, 69% had used a treatment not registered for use in goats. Fifty respondents listed the anthelmintic dosage used, and 50% of those had used a dose rate greater than the recommended label dose. The average frequency of administration of anthelmintic was 2.5 times per annum. Of the 51% of respondents who listed the frequency of their treatments given during the survey period, 16% administered four or more treatments annually to the majority of their goats and 8% administered treatments on an “as needed” basis. Faecal egg count (FEC) had been performed on 72% of properties in at least one of the six years covered by the survey.

These results indicated that the majority of surveyed producers use anthelmintics that are not registered for use in goats and at different dose rates to label. These practises have the potential for increasing the spread of anthelmintic resistance in the GIN populations of goats and sheep. Further, giving dose rates in excess of label recommendations could impact goat safety and/or product residues. Further research is needed to investigate these risks and evaluate more sustainable GIN control options for goat herds. In addition more effective dissemination of information is necessary for the improvement of the Australian goat industry.

1. Introduction

Goat is one of the most widely consumed meats globally and Australia is the largest goat meat exporter, with approximately 95% of production exported, to the value of AUD243.2 million in 2015 (O'Connor, 2016). In addition Australia's domestic annual goat slaughter doubled over the period from 2003 to 2015 to 2.14 million head. Australian producers also run dairy goats and some Angora goats for fibre production. Agrifutures (2017) estimated annual Australian goat milk production to be 16 million litres, with a farm gate value of AUD20M.

Gastrointestinal nematodes (GINs) are a major cause of economic loss in ruminant production systems worldwide, with direct losses due to mortalities and indirect losses due to decreased productivity and cost of control (Várady et al., 2011). Some published research on management practices and sustainable control of GINs in goats is available

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(Torres-Acosta and Hoste, 2008; Hoste et al., 2010; Várady et al., 2011; Lanusse et al., 2014), however very little research has been conducted in relation to Australian goat production practices.

There are comparatively few anthelmintics registered in Australia for use in goats (Wormboss, 2018). This is thought to result in many goat producers using anthelmintic treatments registered for other ruminants at label or other dose rates. In Australia, off-label use of chemicals in food producing animals requires a prescription from a veterinary practitioner (Lyndal-Murphy et al., 2007), as there can be significant implications for goat safety and product integrity (Hoste et al., 2010). In addition, concerns related to chemical residues occur with the use of off-licence treatments in meat and dairy animals.

Treating goats with anthelmintics at doses registered for sheep can also have significant implications for the development of anthelmintic resistance in GINs (Jackson et al., 2012). In addition, a high percentage of adult goats retain the oesophageal groove reflex of kids, thereby diverting oral anthelmintics to the abomasum rather than the rumen, thus reducing absorption (Hennessy, 1994).

For the long-term sustainability of the goat industry in Australia, it is important to consider viable chemical and non-chemical GIN control alternatives. This work aimed to investigate current perceptions, knowledge and attitudes of Australian goat producers about GINs and the GIN control practices. Anthelmintic usage, including products not registered for use in goats, and preferred GIN information delivery channels were of particular interest.

2. Materials and methods

2.1. Survey

A questionnaire was designed and distributed electronically using Survey Monkey (https://www.surveymonkey.com), or via hard copy. The questionnaire was promoted to goat producers via information articles distributed in relevant Australian publications, associations (Boer goat breeders, Goat Industry Council, Mohair Australia and Meat and Livestock Australia), government veterinarians and at a major sale and producer field day. It consisted of 30 open or closed questions to collect data on general husbandry, farm location, grazing area, species kept, goat number and enterprise type, producer experience in the industry, producer opinions on the GIN situation in Australia including resistance, health impacts and the reason for the responses given, worm control strategies, source of worm control advice and producer opinions on availability of information on anthelmintics and effective nematode control programs. Questions further collected data on drench type used, dose and frequency of treatments and rated the monitoring of GIN burdens with FEC.

2.2. Data analysis

Survey responses were collected in the period May 2014 to January 2015. As the data on GIN practises were required for the same 12-month period from all respondents, they were asked to provide data for the previous calendar year of 2013, with one question related to FEC monitoring also related to the years 2009–2014. The data were summarised in a spreadsheet (Microsoft Excel for Mac 2011 Version 14.4.8). Descriptive analysis of responses was summarised as count data and percentages in Excel. Regression analysis (WALD test) was conducted using Genstat (© 2000–2012 VSN International Ltd., Hemel Hempstead, UK) to investigate potential influences of experience, production type, other species kept on farm and number of goats kept on producer perceptions and sources of information about GIN control.

3. Results

Eighty-eight responses were received, with goats the only livestock kept on 40 properties, and combinations of goats and sheep, goats and beef cattle or goats and dairy cattle produced on 13, 16 and 2 properties respectively. A combination of goats, sheep and cattle were kept on 17 properties. Forty-four of the respondents had run goats on their current property for more than ten years. Eighteen respondents had run goats on their current property for one to three years, thirteen respondents for four to six years and thirteen for seven to ten years.

Table 1
Number of properties and goat herd size for different goat production systems from producer survey (n = 88) in 2013. NS is not specified, mini refers to miniature goat breeds.

Number of goats	Enterprise						Number of properties
	Meat	Dairy	Fibre	Mini	Mixed	NS	
< 20	4	12	1	2	2	0	21
21–50	4	4	3	0	1	0	12
51–100	9	2	0	0	1	0	12
101–500	15	5	10	0	3	0	33
> 500	2	2	3	0	1	0	8
NS	0	1	0	0	0	1	2
Total	34	26	17	2	8	1	88

Total goat numbers on each property in the survey period and different goat production systems are summarised (Table 1). Three of the goat properties identified as organic. The majority of responses were received from goat producers based in either New South Wales or Victoria, with properties located in a range of regions throughout these states (Fig. 1).

Seventy-nine respondents thought that GINs were a problem for the Australian goat industry. The reasons given as to why GINs were considered a problem are summarised in Table 2.

Seventy-five percent of respondents thought that GINs had caused production losses or health impacts for their goats during the last five years.

With regard to anthelmintic resistance, 7% believed that anthelmintic resistance was not a problem at all, 93% acknowledged anthelmintic resistance was a problem in Australian goats herds, with 25% of these reporting their properties as being affected.

Eighty-one percent of respondents thought there were not enough chemical products currently registered in goats for effective GIN control. With regard to anthelmintic products used by respondents for GIN treatments during the survey period, 63% of respondents used single active products not registered for use in goats and a further 37% treated animals with anthelmintics containing a combination of active ingredients which were not registered for use in goats. Registered single active drenches were used by 37% of respondents.

Seventy-five respondents provided detail about anthelmintic treatments, of these 77% reported using a product that was not registered for use in goats. Products registered for use in sheep were used by 90% of these producers and 21% had used pour on or injectable cattle products on at least one occasion. Only 50 respondents specified the dose of anthelmintic product used and 50% of these had used a product at greater than the recommended label dose. Though producers were not specifically asked this question, four respondents mentioned receiving veterinary advice when choosing an anthelmintic product.

The average treatment frequency, for the 51 respondents who listed the frequency of their goat treatments administered during the survey period, was 2.5. The annual drench frequency is presented in Fig. 2. Eleven respondents had administered four or more treatments in the survey period and four respondents administered treatments on an "as needed" basis.

Less than ½ of the respondents recorded the timing of treatments. Of the 261 listed treatments given in 2013, 31% were administered during the summer months, 17% in autumn, 29% in winter and 23% during spring.

Seventy-four respondents had a quarantine program for newly

Fig. 1. Map of distribution of 2013 Australian goat survey participants (n = 88) pinpointed by postcode.

Table 2
Submissions from producers as to why gastrointestinal nematodes were a problem on Australian goat properties.

Reason	n
Personal experience with worm problems in goats	18
Overstocking	13
Lack of registered products	13
Industry members with inadequate GIN control knowledge	12
Drench resistance	9
High risk environment	8
Have heard or been told worms are a problem in goats	7
Goats more susceptible	4

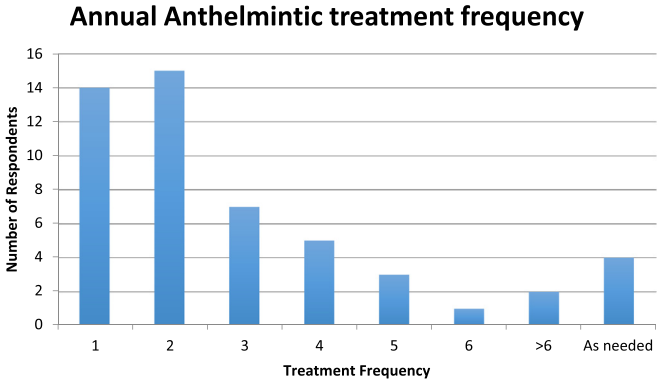

Fig. 2. Distribution of drench frequency in Australian goat herds for year 2013, n = 51.

introduced goats, with 68% including a GIN treatment and 82% isolating new stock. Eight respondents had a closed herd system.

Sixty-five respondents reported using other non-chemical strategies of worm control. The methods of these respondents included rotational grazing (65%), mineral supplementation (17%), other feed additives (11%) and housing (1.5%), and 12% used a combination of these.

Sixty-three of the respondents had monitored parasites in their goats at some time over the previous 6 years with nematode faecal egg count (FEC). Respondent use of FEC varied from 23% to 36% across the surveyed years. Twenty-five respondents reported having never used FEC to monitor worm burdens.

Over half (57%) of respondents indicated they felt there were enough resources available for them to make an informed decision about goat GIN control. With regard to sources of information, 86% of respondents indicated they accessed on-line and social media, however only 23% indicated the internet and social media to be their most trusted source of external advice (Fig. 3). The most trusted source of external advice were veterinarians (65%). Other trusted sources were neighbours (7%), anthelmintic resellers (3%) and agricultural consultants (2%).

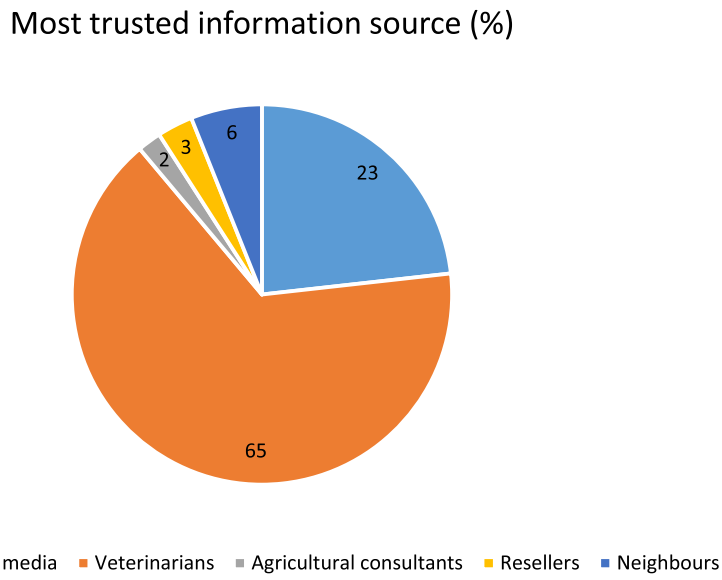

Fig. 3. Most trusted external source of parasite management information for Australian goat producers, $n = 88$.

4. Discussion

Calculation of a response rate for this study is difficult because the number of goat owners who had the opportunity to complete a survey cannot be determined accurately, due to the electronic distribution, which provided convenient, cost effective and fast access to a wide range of goat producers (Cobanoglu et al., 2001). However, the cohort of producers participating in this study ($n = 88$) represented a wide range of farm sizes, production systems and levels of experience.

The potential biases linked to the sample of respondents are in relation to the geographical distribution of respondents, who were primarily from the states of New South Wales and Victoria. The low representation from Queensland, northern Western Australia or the Northern Territory where producers are more likely to have rangeland enterprises, and represent a significant proportion of Australian goat production (O'Connor, 2016) means results from this study might not be representative of this production system. Due to the management systems involved and local climate, GINs will likely have a less significant influence on production in these enterprises than those that are pasture-based.

Nevertheless, this study provides an insight into the significance of GINs among Australian goat producers. According to the results obtained, a vast majority (90%) of respondents considered GINs to be a problem for the Australian goat industry, causing production losses or health impacts for their goats over the five years.

Notably, this study also documented the previously anecdotal concerns that many Australian producers administer anthelmintic products to their animals that are not registered for goats because of a lack of field efficacy of the limited number of products registered for use against GINs in goats in Australia. This concern was supported in our survey, with most (82%) respondents reporting the use of at least one anthelmintic product that was not registered for goat use in Australia in the survey period.

Currently registered anthelmintics for goats in Australia are abamectin, fenbendazole, oxfendazole, albendazole and morantel citrate, and there are many published reports of important GIN resistance to these in Australian sheep (Green et al., 1981; Rolfe, 1993; Waller et al., 1995; Besier and Love, 2003; Playford et al., 2014) and goats (Gillham and Obendorf, 1985) as well as in goats worldwide (Jackson et al., 1992; Chartier et al., 2001; Waruiru et al., 1998; Zajac and Gipson, 2000). As goats in many parts of the world are primarily infected with GINs that could also infect sheep (Jackson et al., 2012), there is a risk of transfer of anthelmintic resistant GINs between these two host species. This appears to be supported in Australia and New Zealand by the detection of early cases of moxidectin and monepantel resistant GINs from goats (Lyndal-Murphy et al., 2007; Scott et al., 2013) and is of concern as this survey found more than a third of respondents had both sheep and goats on their property.

The effective use of non-registered anthelmintics in goats is further complicated by differing dose rates required, with half of respondents who used an unregistered product, reporting the treatment was administered at the standard label dose for sheep or cattle. The pharmacokinetics of anthelmintics have been thoroughly researched with the differences in the metabolism and required dose rates between sheep and goats well documented (Scott et al., 1990; Hennessy et al., 1993; Alvinerie et al., 1999; Gokbulut et al., 2010; Várady et al., 2011; Lanusse et al., 2014).

There are no topical or injectable anthelmintic products registered for use in goats in Australia. However, this survey showed that some Australian producers are using some non-oral anthelmintic formulations. Studies using topical administration of ivermectin or eprinomectin in goats using a bovine dose rate have resulted in risks of limited efficacy against a range of GINs (Dupuy et al., 2001). Eprinomectin is frequently used in goat enterprises overseas because it has a nil milk withholding period (De Souza Chagas et al., 2007) and widespread GIN resistance has been reported in Swiss dairy goats (Murri et al., 2014). When administered topically to goats at double the cattle dose (1000 µl/kg bw) eprinomectin has been shown to be more effective than at the standard dose against natural infections, but was still not as effective as oral or subcutaneous eprinomectin or other proven anthelmintics (Gawor et al., 2000; Lespine et al., 2003; Cringoli et al., 2004). Utilisation of non-registered anthelmintic products, particularly pour-ons, for goats at standard label doses for other livestock is likely to lead to increases in anthelmintic resistance due to relative under dosing (Prichard, 1990; Woodgate and Besier, 2010).

Exports of Australian goat meat could be impacted if chemical residues are found in goat meat products. Therefore it is particularly important that goats intended for human consumption are not treated with chemicals that could result in excess chemical residue levels in meat or milk. Half of respondents who detailed doses of anthelmintic treatments in the survey period administered doses greater than those required for sheep. And while this practise may be a more sustainable form of GIN control it is however an illegal practise unless the producers are acting on veterinary advice. Hence this practise could have

serious consequences for both individual producers and the national goat industry due to compromised host safety and/or goat product chemical residue violations.

As the majority (65%) of respondents nominated veterinarians as their most trusted source of information about GIN control, wider education and support of private and government veterinarians in Australia about off-label effective and sustainable anthelmintic use in goats would assist in reducing the risks of anthelmintic misuse within the Australian goat industry.

Given that the majority of respondents expressed their concerns at the lack of choice of anthelmintic products registered for goats in Australia, the registration of more anthelmintic groups, including combination products are needed.

Drench frequency by Australian producers is consistent with that found in surveys of goat producers in France, Denmark or New Zealand, which reported mean annual numbers of treatments between 2.74 and 12 (Kettle et al., 1983; Pearson and MacKenzie, 1986; Maingi et al., 1996; Hoste et al., 2000). The development of anthelmintic resistance has been associated with the frequency of anthelmintic administration, as the selection pressure for resistance increases when the interval between treatments decreases (Prichard, 1990; Woodgate and Besier, 2010). Hence, it should be recommended to decrease the frequency of anthelmintic treatment to a minimum to maintain satisfactory parasite control whilst also slowing the development of anthelmintic resistance (Coles and Roush, 1992). The location and climate of the property and the temperature ranges for development of the prevalent GIN species should be considered when recommending a specific and appropriate treatment frequency (Coles, 1986). Given the distribution of respondents to our survey, it is likely that at least some producers are treating their goats excessively and unsustainably relying solely on chemical treatments for GIN control.

As GIN resistance to many of the anthelmintics used in goats is widespread in Australia, an effective quarantine programme for goats introduced into a herd is an important part of sustainable goat GIN control (Lyndal-Murphy et al., 2007; Leathwick and Besier, 2014). Whilst this survey found 84% of respondents were utilising a quarantine protocol, with the majority (82%) of these isolating new animals after arrival for a period of time, many did not treat goats on arrival. It is likely that this practise is inadequate as there are no combination or new generation anthelmintics (i.e. monepantel or derquantel) currently registered for use in goats in Australia, This gap in goat producer knowledge and practises needs to be addressed.

The risks of selecting for and disseminating anthelmintic resistance within small ruminant GIN populations in Australia require GIN control programmes that rely less on chemical treatments, known as integrated parasite management (IPM) (Niezen et al., 1996; Waller and Thamsborg, 2004; Waller, 2006; Kahn and Woodgate, 2012). IPM aims to balance GIN infection levels and profitability, as a result of a strategic mix of chemical and non-chemical parasite control strategies. This in turn requires sound knowledge of parasite biology and epidemiology, effective chemical and non-chemical based control activities and monitoring of parasite levels to allow evidence-based intervention. Importantly there is a need for effective transfer of knowledge and adoption by Australian goat producers.

As low as a quarter of respondents reported monitoring the internal parasite burden of their goats using faecal egg counts (FEC) during a particular survey year, with many not monitoring worm burdens using FEC at all over the survey period. This is less than compared to the Australian sheep industry, where approximately 50% of producers surveyed used FEC to monitor worm burdens, and where increased monitoring is still promoted for more effective and sustainable internal parasite control (Thompson and Reeve, 2011; Woodgate and Love, 2012). Our results show that increased internal parasite monitoring is required within the Australian goat industry, with the FAMACHA© system for clinical evaluation being a feasible alternative to FEC for goat producers in areas of *Haemonchus contortus* prevalence. This requires a change in practises among Australian goat producers and the drivers necessary for these changes warrant further research.

Non-chemical based strategies were utilised by many producers to assist GIN control, with rotational grazing the most common strategy mentioned. Traditional small ruminant grazing methods to support GIN control (Michel, 1985), including shifting treated animals onto pasture with low levels of worm contamination, have provided good control in the past, but have also selected potently for anthelmintic resistance. In developing locally applicable parasite control strategies, the relationship between climatic conditions and relative nematode abundance is an essential consideration (Besier and Love, 2003) to ensure treatment timings allow for adequate levels of susceptible parasites to be *in refugia*.

Producer knowledge and adoption of novel non-anthelmintic methods of GINs suggested for sheep, such as the use of nemataphagous fungi to reduce larval populations on pasture, the introduction of pasture species containing condensed tannins or other active compounds with anthelmintic activity, vaccination against nematodes and breeding for GIN resistance (Besier and Love, 2003) require evaluation.

Modified rotational grazing strategies have long been proposed as effective alternatives for more sustainable GIN control in Australian sheep (Kelly et al., 2010; Colvin et al., 2012; Walkden-Brown et al., 2013). Limited research into these strategies for goats in wet tropical environments is available (Barger et al., 1994), however more detailed investigation of what goat producers are currently doing and potential application of sheep strategies for goat production are recommended. This would need to be done for all relevant climates where goats are raised in Australia.

Mineral supplements were provided by some producers to their goats to assist GIN control. The use of copper sulphate (Burke and Miller, 2008) and copper oxide (Chartier et al., 2000; Martınez Ortiz de Montellano et al., 2007) to aid GIN control has been investigated with the use of copper oxide wire particles recently being suggested as an alternative to conventional anthelmintics against *Haemonchus contortus* where resistance is present (Waruiru et al., 2017). Copper supplementation, however, requires careful consideration to prevent toxicity risk (Martınez Ortiz de Montellano et al., 2007) and further investigation of goat requirements for mineral supplementation in a variety of production systems is required before endorsement of copper supplements for GIN control.

5. Conclusion

Our producer survey showed that there are concerns about effective and sustainable practises implemented within the Australian goat industry in relation to internal parasite control. Notably, almost half the respondents stated that there was inadequate information available to support effective GIN control. Extension strategies that lead to effective knowledge transfer are required, therefore as our study suggests that veterinarians are the most trusted source of advice with regard to GIN control strategies for goat producers, we suggest that the veterinary profession should be involved in future extension programs.

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Ethical statement

No animal experimentation was conducted in this research.

Approval for conduct of this research was granted by Charles Sturt University's Human Research Ethics Committee.

Declaration of Competing Interest

The authors declare that they have no conflict of interests.

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