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Reduced anthelmintic use on 13 New Zealand sheep farms: farmer motivations and practical implementation

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ABSTRACT

Aims: To describe the personal drivers, sources of information and gastro-intestinal parasite control methods used by a group of New Zealand sheep farmers identified as low users of anthelmintic (AHC), and their perception of the efficacy and impacts of this approach.

Methods: A convenience sample of 13 sheep farmers farming with a policy of reduced AHC use (no pre-determined routine treatments of ewes >19 months old and/or lambs not routinely treated at pre-determined intervals from weaning through to late autumn) were identified. Semi-structured interviews were conducted regarding their farming philosophy, motivations for reducing AHC use, perceptions of the impacts of farming with reduced AHC use, and parasite control practices. Semi-quantitative data were analysed using descriptive statistics for demographic data and categorising participants' use of AHC and non-chemical control methods. Qualitative data regarding participants' motivations, approaches and rationale were analysed by systematic analysis of the transcripts and distillation of key concepts.

Results: Participants had been operating with reduced AHC use for 3 to ≥20 years. Key motivators for reducing AHC use were a diagnosis of anthelmintic resistance (AR) or concerns about AR developing. Parasite management information came from a wide range of sources. All respondents expressed overall positive views regarding the impacts of reduced AHC use but detailed information was not available.

All identified that regular monitoring, based primarily on subjective animal and non-animal factors was important for their parasite control strategy. Most used faecal egg counts (FEC), often in an *ad hoc* manner. Five never treated adult ewes, two routinely treated ewes prior to lambing with short-acting AHC and the remainder occasionally treated a small number in low body condition. Four routinely treated some or all lambs at 28–30-day intervals from weaning to late autumn while the remainder based their treatment decisions for lambs on monitored information. All placed heavy emphasis on feeding sheep well, ensuring high post-grazing residuals, and cross-grazing.

Conclusions: AR was a key motivator for participants to reduce AHC use, and a range of information sources and decision-making processes were used. Key parasite management practices were monitoring, primarily using subjective assessments, emphasis on feeding stock well and cross-grazing.

Clinical relevance: The rising prevalence of AR will likely result in increasing the motivation for sheep farmers to reduce their AHC use. Veterinarians will play a key role in providing advice and assistance to facilitate changes in parasite management.

Abbreviations: AHC: Anthelmintic; AR: Anthelmintic resistance; BCS: Body condition score; FEC: Faecal egg count; SCOPS: Sustainable control of parasites in sheep

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Introduction

Worldwide, internal nematode parasites are one of the most important animal health challenges for sheep farmers, and for the past 50 years anthelmintics (AHC) have been used as a key tool for their control (Gilleard *et al.* 2021). The issue of anthelmintic resistance (AR) in New Zealand was first highlighted in the early 1980s (Kemp and Smith 1980) and is a growing concern in New Zealand and globally (Gilleard *et al.* 2021; Charlier *et al.* 2022). There are no recent data on AR prevalence

from randomly selected New Zealand sheep flocks, as the last study to investigate this was undertaken in 2004–2005 (Lawrence *et al.* 2006). However, non-peer reviewed data from one of New Zealand's commercial veterinary laboratory networks showed that in 2016–2017, 11% of 141 flocks tested had at least one nematode species with resistance to triple combination AHC (McKenna 2018), while data from the same laboratory network for 2021–2022 reported that 33% of 160 flocks had *Trichostrongylus* spp. with resistance to triple

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combination AHC (Riddy 2022). Notwithstanding that these data may be biased towards farms with suspected AR, they indicate a high and increasing prevalence of AR in New Zealand sheep flocks.

Since the 1980s farmers have been encouraged to employ a range of strategies to reduce the risk of developing AR on their farms and one of these has been to avoid over-use of AHC (Leathwick and Besier 2014). However, in a survey of 74 New Zealand sheep farmers, Lawrence *et al.* (2007) identified that the frequency of AHC use in lambs and ewes had remained virtually unchanged compared with previous surveys undertaken in the 1980s and 2000s (e.g. Kettle *et al.* 1981; Brunsdon *et al.* 1983; Sharma *et al.* 2005). Lawrence *et al.* (2007) also reported that the use of persistent activity AHC formulations administered to ewes prior to lambing, which have been demonstrated to select for AR (Lawrence *et al.* 2006; Leathwick *et al.* 2006), had increased compared with earlier surveys. Similarly, in Australia, there was little change in AHC use between 2003 and 2019 (Colvin *et al.* 2021). Assuming these trends have continued, it is likely that New Zealand sheep farmers continue to have high AHC use.

In New Zealand a national worm management strategy, “Wormwise” (McAnulty and Cook 2019), was developed in 2005 to provide an evidence-based, impartial resource for farmers and veterinarians about internal parasite control. This includes a handbook containing information about internal parasites and tools for their management, which emphasises the importance of monitoring to make informed parasite control decisions. Also discussed are non-chemical tools for worm management which include pasture management (keeping post-grazing residuals high and using hay and silage aftermaths, fodder crops and new pastures as low-contamination feeds), stock management (consideration of stocking rate, grazing young animals ahead of older stock, and alternation of grazing species), and use of parasite resistant host genetics. It also emphasises the use of refugia (a worm population not exposed to AHC) to delay AR (McAnulty and Cook 2019). However, there is no published information on whether and how these can be successfully implemented on New Zealand farms to enable parasite control with reduced AHC input.

However, international researchers have identified that farmers utilise a range of sources for information on parasites (e.g. Morgan *et al.* 2012; Moore *et al.* 2016; Jack *et al.* 2017). While these studies surveyed large numbers of farmers, their use of questionnaires limited the depth and breadth of information obtained. In addition, notably few studies have explored these themes in the New Zealand context, and none have examined farmers who are specifically focused on reducing AHC use.

For a group of sheep farmers identified as low users of AHC, this study aimed to describe the personal drivers

and sources of information used to manage parasites, the practices used to reduce AHC use, and the farmers’ perceptions of the efficacy and impacts of this approach.

Materials and methods

Participants

A convenience sample of rural professionals (veterinarians and farm advisors) was asked to purposively identify from their client base, farmer participants they believed to be low users of AHC. A minimum of 12 participants were sought.

Contact was made with 15 rural professionals (“nominees”) located throughout New Zealand and whose role was primarily focused on sheep and beef cattle, who were known to be interested in parasitology through attendance at continuing professional development events and had spent a minimum of 5 years in their current practice/consulting area. Nominees were asked if they anecdotally knew of farmers that had low or reduced AHC use compared with others in the area with similar farming systems. Eleven nominees responded and each identified one to five farmers who, in their opinion, had reduced AHC use compared with other farmers in their area, and provided brief details of potential participants’ parasite control practices. Nominees contacted potential participants to gain consent for their contact details to be passed to the researchers. Thirty-one potential participants were identified by the nominees, of whom 18 were selected to approach based on the details of AHC use provided by the nominees and aiming to have a diversity in farm location and system. A researcher (Author AR) contacted these potential participants by phone, the project was explained to them, and they were briefly interviewed on their AHC use in ewes and lambs, and their general parasite control practices. At that stage two potential participants were rejected, one because their AHC use was relatively high, and one who was unavailable to participate. A visit time was scheduled for the remaining 16 and they were emailed a project information sheet and consent form.

Definition of reduced AHC use

There are limited data on typical AHC use in sheep flocks in New Zealand and no recent data. However, a survey of 74 New Zealand sheep farmers for the 2004–2005 season reported that 89% sometimes or always treated ewes at least once a year, often with a long-acting AHC formulation prior to lambing, and ewes received a mean of 1.5 treatments per annum (Lawrence *et al.* 2007). Lambs were sometimes or always treated prior to weaning on 77% of farms and then on most farms they were routinely treated every month resulting in a mean of 5.5 doses (Lawrence *et al.* 2007) from birth to early winter. Therefore, in this study reduced AHC use was

defined as sheep flocks in which ewes > 19 months of age were not routinely treated (i.e. not all ewes were treated at pre-determined fixed times) and/or lambs were not routinely treated at pre-determined intervals (i.e. not treated regularly at 28–30-day intervals) from weaning through to early winter.

Data collection

Prior to beginning data collection, an expert group comprising two parasitologists, a veterinarian with specific interest and expertise in parasitology, a veterinarian and scientist from Beef + Lamb New Zealand Ltd. (the funding body) and the research team met to identify key areas to discuss in the interviews. This informed the development of an interview guide (Supplementary Information), which was reviewed within the expert group.

Before beginning the interview, participants signed a consent form. To ensure anonymity, participants were assigned an alphabetical identifier based on the chronological order in which they were interviewed, their farm location was reported based on which of the five regions defined by Beef + Lamb New Zealand Ltd. (Anonymous 2023a) they were in, and their farm size was reported as falling within an effective hectare range rather than reporting actual farm size. The inclusion of human participants for this study was assessed as low risk by the Massey University Human Ethics Committee, application number 4000025667.

Interviews were conducted between May and July 2022. Using the interview guide, a semi-structured face-to-face interview was conducted with each participant at their residence. The order in which the topics were discussed varied depending on how the interview progressed. Open-ended questions were used and, where participants' responses were unclear or ambiguous, further questioning was used to provide clarity. Two researchers (author AR, a specialist small ruminant veterinarian and author KH, an environmental scientist with a qualitative research background), working together, conducted the interviews. Key sheep flock management events (e.g. mating, lambing, etc.) and parasite control events including AHC treatments were mapped out on a hand-written calendar.

Interviews lasted 105–150 minutes and were audio recorded. Recordings were transcribed using the transcription software Otter.ai (Mountain View, CA, USA) and then an independent transcriber was used to identify and correct errors in the initial transcripts and add unique and/or specialised terminology not recognised by the software (e.g. boluses, two-tooths, Zolvix Plus etc.).

Data analysis

The interviews yielded a mixture of demographic and semi-quantitative data relating primarily to farm

characteristics and parasite control strategies, and qualitative data relating to why participants behaved as they did. Demographic data was briefly summarised using descriptive statistics. AHC use was summarised by utilising the calendar and transcript for each participant to map AHC use for each stock class (i.e. ewes, replacement ewe lambs and non-replacement lambs). Within each stock class, participants with similar AHC use were then grouped together and their AHC use described. To analyse qualitative content the interview transcripts were systematically analysed by authors AR and KH. This was an iterative process using inductive coding for key content related to the themes identified within the data (Braun and Clarke 2013): participants' rationale behind their approaches to parasite control including their farming philosophies, motivation for reduced AHC use, sources of information and decision making for parasite management, perception of the impacts (financial and otherwise) of reduced AHC use, their use of parasite monitoring tools, AHC and non-chemical parasite control methods and their understanding of parasite epidemiology and control. Authors AR and KH met periodically during July, August and September 2022 to compare coding, identify and discuss any discrepancies in the analysis, and confirm the themes identified. The other members of the project team (authors JR and DG) provided oversight and scrutiny. Additionally, through analysis of the transcripts, the authors categorised participants' level of use of non-chemical parasite control strategies as high, moderate, low, not used or not applicable.

Results

Quantitative analysis

Participants and farm demographics

Sixteen participants were interviewed. After careful retrospective review of their AHC use practices, 13 (identified as A–M) comprehensively met the definition of reduced AHC use within their sheep farming system (as specified above) and were included for analysis. They were located throughout New Zealand (Table 1) and had been farming with reduced AHC use for a minimum of 3 and a maximum of > 20 years. The mean total effective farm size of enrolled farms was 1,240 (min 250, max 2,500) ha compared to the New Zealand mean of 700 ha (Anonymous 2023a). Enrolled participants were engaged in some or all the following forms of sheep farming: breeding, finishing, trading and stud breeding. All enrolled properties farmed both sheep and cattle with sheep to cattle ratios (based on stock units) ranging from approximately 80:20 to 10:90. All farmed coarse-wool (wool fibres \geq 26 μ m) sheep breeds while two also farmed fine-wool (wool fibres < 26 μ m) sheep breeds (Table 1).

Table 1. Summary of the location, farm size, sheep system and sheep to cattle ratios in a group of 13 New Zealand sheep farms identified as low users of anthelmintic and enrolled in a study to investigate the personal drivers and sources of information for this approach and the gastro-intestinal parasite control methods employed. All participants treated all lambs at weaning.

Farm ID	Location ^a	Farm size range ^b	Sheep system ^c	Approx. sheep:cattle ratio
A	2	500–749	Breeding, finishing, coarse wool	70:30
B	3	250–499	Breeding, coarse wool	70:30
C	3	≥ 1,000	Breeding, finishing, coarse wool	60:40
D	3	750–999	Breeding, finishing, stud, coarse wool	60:40
E	1	750–999	Breeding, finishing, coarse wool	10:90
F	1	250–500	Breeding, finishing, coarse wool	60:40
G	5	≥ 1,000	Breeding, finishing, coarse and fine wool	80:20
H	5	≥ 1,000	Breeding, finishing, coarse wool	80:20
I	4	≥ 1,000	Breeding, finishing, coarse wool	30:70
J	4	≥ 1,000	Breeding, finishing, coarse and fine wool	80:20
K	2	250–499	Breeding, finishing, stud, coarse wool	80:20
L	2	750–999	Breeding, finishing, coarse wool	70:30
M	2	750–999	Trading, breeding, finishing, coarse wool	Varies ^d

^aLocation based on Beef + Lamb New Zealand Ltd. regions of New Zealand. 1 = northern North Island, 2 = eastern North Island; 3 = western North Island; 4 = northern and central South Island; 5 = southern South Island.

^bFarm sizes are given within a range of effective ha to protect anonymity.

^cCoarse wool from sheep breeds with wool fibres $\geq 26 \mu\text{m}$; fine wool from sheep breeds with wool fibres $< 26 \mu\text{m}$.

^dThe number of sheep and cattle fluctuates within and between years as a result of buying and selling activity.

Qualitative analysis

Seven themes were identified in the qualitative analysis. These are described below.

Theme 1. Farming philosophies and motivations for reducing AHC use

When asked to describe their philosophy of farming and what was most important to them, participants expressed diverse priorities. However, having pride in their stock and wanting to feed them well was expressed by all, while many also characterised themselves as being proactive and having good attention to detail. Participants A, H, I and J wanted to farm “resilient” stock, using terms like “robust”, “can hack the pace” and “suited to their environment” to describe this. Some emphasised that for them, productivity was secondary to other goals such as sustainability and work-life balance, but in contrast others described themselves as highly competitive and production oriented.

Five had had triple-combination (benzimidazole, levamisole and macrocyclic lactone) AR diagnosed in their sheep system within the previous 3–5 years and this was their primary driver for changes in parasite management, including reduced AHC use. The reasons for reduced use amongst the remaining eight participants varied but all had a high degree of awareness of AR, describing this as the main factor or a very important factor contributing to their decision. In line with their farming philosophy of wanting more “resilient” animals, four wanted to breed sheep they perceived to be less reliant on AHC, while an additional two had a desire to farm with lower chemical use more generally.

Theme 2. Sources of information about parasite management

Participants described using a wide range of information sources about parasite management. All

identified veterinarians and approximately half identified scientists and Wormwise as being very useful or important. Rural newspapers, farmer discussion groups and the internet were described as important sources by a small number of participants. However, except in the context of farmer discussion groups where the experts invited to speak were the main focus, none of the participants described other farmers such as relatives, neighbours or friends as important sources of parasite information. Most participants believed that there is plenty of information available to farmers about parasite management, but some expressed the view that it can be overwhelming or difficult to navigate. Others expressed concern about the prevalence of misleading information from drench manufacturers, retailers, and vets.

Theme 3. Decision making about parasite management

There was a wide range in how participants described their process of planning and implementing their parasite management regime, particularly the degree to which they collaborated with experts. Five described very close working relationships with their vets or advisors, characterised by high levels of communication and trust. These farmers described regularly engaging in in-depth discussions about all aspects of parasite management. They also described other sources of information that they sometimes engaged with, but it was clear that their vet or advisor was their primary source of information, and their parasite management regime was a result of collaborative decision making. These participants emphasised the importance of finding “the right person” with whom to make collaborative decisions and described the key relationship characteristics as trust and rapport, ease of contact and communication, being able to have open, frank conversations, and having a similar appetite for risk. It is important to note that two of these participants

had partners who were veterinarians who were integrally involved in parasite decision-making.

At the opposite end of the spectrum, five participants exhibited a very low level of collaboration with veterinarians or advisors and described making decisions independently based on information obtained from a wide range of sources such as Wormwise, the internet, scientists, rural newspapers and discussion groups. While their veterinarian or advisor was usually one of these sources, they had minimal, if any, direct input into the farmers' parasite management decisions. Two described sometimes actively ignoring expert advice relating to parasite management if they did not believe the advice was in line with their own thinking or instincts.

In between these two extremes, the remaining participants collaborated to varying degrees with their veterinarian or other animal health advisors, alongside using the other information sources described above.

Some views shared by participants and regarding veterinarians, were expressed across the collaboration spectrum. Many identified veterinarians as their first port of call when things went wrong but several expressed concern that some veterinarians lack specialised knowledge about sheep generally and sheep parasite management specifically. The differences of opinion about parasite management between different veterinarians was another issue raised. Several raised concerns regarding the potential conflict of interest for veterinarians working at practices where selling AHC is a significant source of revenue while others contrasted their experiences of vets that promoted products compared with vets that supported them in not relying on AHC.

Theme 4. Perceptions of impacts of reduced AHC use

All participants expressed positive overall views regarding the impacts of reduced AHC use on their farming operations, but none were able to provide detailed information on the financial impacts. For some, this was because they had been farming with reduced AHC use for a long period of time and so did not have anything to compare their current financial performance to. Those who had more recently reduced their use, usually due to a diagnosis of AR, could not quantify the impact of this change because it was just one of many changes they had implemented. Notwithstanding this lack of concrete data, three were confident that reducing AHC use had a positive financial impact, citing cost-savings from reduced purchase of AHC and time spent administering them. Four believed it to be financially neutral while three believed there had been some short-term production or financial impacts but emphasised that these were outweighed by the long-term benefits of either having more "resilient" sheep or their perception

that it would reduce the likelihood of AR development. The remaining three were unsure of the financial impacts. Some also described the positive impact of reduced workloads through less time spent administering AHC.

Theme 5. Practices used to monitor nematode parasite status

Monitoring to enable parasite control decisions: All participants stated that regular monitoring was an important aspect of their parasite control, but they primarily relied on subjective assessments to determine whether AHC treatment was required. Use of quantitative methods (faecal egg count (FEC), liveweight and body condition score (BCS)) were sometimes used, but often in a non-structured or non-systematic manner. Many participants strongly expressed that they prided themselves on their observation skills and indicated that multiple factors, both animal and non-animal, were considered when monitoring for parasites, rather than relying on a single piece of information. Animal factors included visual cues, age, stock class and, sometimes, growth or BCS targets and/or FEC. Non-animal factors included time since last AHC treatment, weather conditions, feed on offer (type, quality, and quantity), and consideration of the likely parasite larval challenge animals were being exposed to, based on the paddock grazing history, for example:

Weather history, paddock history, a little bit of FEC testing ... what sort of feed they have been on, so you expect to see what sort of growth rates they've been doing ... how they look (K).

A majority used the term "stockmanship" to encapsulate this multi-factor decision-making. However, this rarely included any formal recording of data.

Visual cues: The visual cues used by participants could be broadly categorised as either perceived poor thrift, or diarrhoea. Multiple colloquial descriptors, based on a visual appraisal of perceived poor thrift and diarrhoea, were used by participants. As H described, "they just start to look like they need a drench".

The presence of faecal staining of the perineum of sheep ("dags") was viewed as indicative of parasites by some participants while others attributed it to other factors such as good feeding.

Liveweight gain and BCS: While many participants mentioned liveweight gain as a factor they monitored, most indicated that they either did not weigh stock or did so infrequently and weight gain was primarily assessed by observation. Only D and K put any emphasis on liveweight gain assessed using weigh scales to aid in parasite control decisions. Most also mentioned "condition" but the majority did not regularly assess BCS and in many cases appeared to base it on visual observation of the sheep rather than palpation of their lumbar spines. Assessing "condition" was mainly used

to identify thin ewes during yarding for key management events and on some farms these ewes would be treated with AHC. After about May/June, some participants also assessed “*condition*” of replacement ewe lambs and only treated the poorer-conditioned animals.

Faecal egg counts: All participants had used FEC at some point during their farming career but their current use and attitudes towards them were variable. Those who were utilising FEC at the time the study was conducted could broadly be categorised into three groups: those who used them regularly in a structured manner as a key source of information for all AHC treatment decisions for lambs; those who used them one to three times per year at strategic times to help inform treatment decisions; and those who used them in an *ad-hoc* manner to augment subjective assessments of animal and non-animal factors. Overall, the majority of participants appeared to be guided less by scientific standards of best use of FEC, and more by their occasional use as an adjunct decision-making tool to support their subjective assessments.

From weaning to late autumn, C and F used FEC routinely in a structured manner for lamb treatment decisions by assessing individual FEC from 10 lambs per mob 28 days after their previous AHC treatment. A decision on whether to administer AHC was made based on FEC results, consideration of animal and non-animal factors, and often veterinary input. If the decision was made to not administer AHC, they repeated this process every 7–10 days until AHC was administered. They emphasised that they believed objective information was very important in their decision making.

A and I used FEC one to three times a year at strategic times (prior to weaning, in late autumn and/or prior to lambing for in-lamb hoggets (at approximately 1 year of age)) to assist in determining whether AHC treatment was necessary. Participant I had used FEC more regularly in the past and believed they had been helpful in aiding their understanding of what was happening with parasites in their flock. H had recently started occasionally assessing FEC at the same time as treating ewe lambs, with a view to determining whether their routine AHC treatments were necessary.

E, K, G and M would assess perceived parasite burden based on a subjective assessment of animal and non-animal factors and, if they had concerns, would always (G and M) or sometimes (E and K) use FEC to further inform their decision-making on the requirement for AHC treatment. K explained their approach to FEC:

[My use of FEC is] all over the shop, really, but it's just in my own head, just managing what I'm doing and how I'm doing it with a little bit of science behind it. You know, sometimes it's just verifying what you can see. (K)

Participants B, D, J and L had used FEC in the past but had now largely stopped, and the time taken to collect and submit samples, or get the results back, were cited as the major reasons for this. One also expressed concern about the accuracy of FEC results. None of the participants identified the cost of FEC as a concern and the two that did mention cost did so in the context of it being a worthwhile investment.

In general, those who used FEC frequently had a system whereby the amount of time and effort required, and the time taken to get the results back, were not seen as limiting and where they had available support from an advisor in interpreting the results. Most participants would not commit to a specific FEC threshold at which they considered a treatment would be required, and other factors taken into consideration included age and condition of the sheep, time of year, nutritional levels, and workload. Some said a decision would be made in consultation with their veterinarian.

Theme 6. Anthelmintic use and non-chemical control methods

Anthelmintic use in ewes and lambs varied between participants and is summarised in [Table 2](#).

Anthelmintic use in ewes > 19 months of age: Participants' use of AHC for treatment of adult ewes could be broadly categorised into those who did not administer treatments, those who treated a small number of low BCS ewes on an *ad hoc* basis, and those who routinely treated some or all ewes. Most described the importance of good nutrition of their ewe flock to facilitate their approach.

Those who did not treat ewes with AHC either only had a small number of ewes relative to their total stock units and did not consider that they needed treatment (E and M) or, for the previous 7 years or longer, had had a deliberate policy of not treating adult ewes (A, H and I). These latter participants stated that they were seeking to build “*resilience*” in their ewes by eliminating their reliance on AHC, while for H this was also in part a financial decision to reduce their expenditure on animal health treatments. These participants separated and preferentially fed, or culled, ewes in poor BCS, rather than treating them. They subjectively believed that their ewe flocks had become more “*resilient*” through this process but did not have objective criteria to measure this.

Participants B, C, D, F, K, L sometimes treated a small number of ewes on an *ad hoc* basis and primarily made these decisions based on poor “*condition*” and sometimes ewe age and presence of diarrhoea or faecal staining of the perineum. C incorporated FEC into their decision-making while the remainder did not.

G had traditionally treated all ewes with AHC three to four times a year, but since 2019 had been steadily decreasing ewe treatments; in 2021 the only treatment

Table 2. Summary of the reported anthelmintic (AHC) use in a group of 13 New Zealand sheep farms identified as low users of anthelmintic and enrolled in a study to investigate the personal drivers and sources of information for this approach and the gastro-intestinal parasite control methods employed. All participants treated all lambs at weaning.

Farm ID	Target group and anthelmintic use					
	Ewes ^a	Lambs pre-wean	Replacement ewe lambs post-wean	Non-replacement and/or trading lambs	Knock-out treatment ^b	Ewe hogget pre-lamb
A	Never	Always	Routine to late autumn	Infrequent (crop grazing)	Always	Monitoring (usually FEC)
B	Low BCS only	Never	Routine to late autumn	NA (sold at weaning)	Never	NA
C	Monitoring (always FEC)	Never	Monitoring (always FEC)	Monitoring (always FEC)	Always	Monitoring (always FEC)
D	Low BCS only	Never	Monitoring (rarely FEC)	Monitoring (rarely FEC)	Never	Always
E	Never	Never	NA (not kept)	Monitoring (rarely FEC)	Never	NA
F	Low BCS only	Always	Monitoring (always FEC)	Monitoring (always FEC)	Always	Always
G	Fine-wool only, pre-lamb	Never	Monitoring (always FEC)	Monitoring (always FEC)	Never	NA
H	Never	Never	Routine to late autumn	Routine until sale	Never	NA
I	Never	Sometimes	Infrequent (crop grazing)	Infrequent (crop grazing)	Always	NA
J	Routine pre-lamb	Never	Monitoring (rarely FEC)	Monitoring (rarely FEC)	Never	Always
K	Low BCS only	Never	Monitoring (sometimes FEC)	Monitoring (sometimes FEC)	Never	NA
L	Low BCS only	Never	Infrequent (crop grazing)	Routine until sale	Never	NA
M	Never	Never	NA (not kept)	Monitoring (always FEC)	Never	NA

^aEwes > 19 months of age (after mating as a two-tooth).

^bAHC given to young sheep using an AHC anticipated to be highly effective and different from that used at other times. Usually given in early autumn (Leathwick and Hosking 2009).

BCS = body condition score; FEC = faecal egg count; NA = not applicable.

was a short-acting AHC prior to lambing to less than half the ewes, with the intention to stop this practice in 2022. J, despite a strongly expressed desire to minimise AHC use, routinely treated all ewes prior to lambing with short-acting AHC. Their rationale was that the success of their farming system was reliant on high pre-weaning lamb growth rates, and they were concerned that these might potentially be compromised if ewes were not treated.

Anthelmintic use in lambs: AHC use in lambs prior to weaning varied amongst participants (Table 2) whereas at weaning all participants routinely treated all lambs that were staying on the farm. For lambs remaining on farm post-weaning, approaches to AHC use could be broadly categorised into those that routinely administered AHC treatments at pre-determined intervals (every 28–30 days) from weaning until late autumn for some or all lambs (A, B, H and L) and the remainder for whom lamb treatment decisions were based on information obtained from monitoring (as described previously).

For those that utilised routinely administered treatments to some or all lambs, their rationale varied. A and L targeted routine treatments at specific lamb groups (replacement ewe lambs intended to present for breeding at 7–9 months of age, and non-replacement lambs destined for slaughter, respectively) to reduce possible parasite-related compromise in these lambs' growth rates. B viewed routine (28-day interval) treatments as "insurance" because in the past they had experimented with basing AHC treatments on monitoring information (visual cues and FEC) but had subsequently encountered high levels of parasitism in lambs in autumn. H had always had a policy of giving routine (28-day interval) AHC treatments but, in autumn 2021, they twice collected 10 faecal samples from ewe lambs for FEC at the same time as treating them (i.e. the FEC were not used to make treatment decisions, but rather

to determine whether the routine treatment that was given was necessary). In conjunction with their vet, it had been determined that the FEC were low and hence they planned to proactively utilise FEC in the future to aid in treatment decisions and reduce their use of routine AHC treatments in lambs.

As previously described, those who treated based on monitored information used a combination of "stockmanship" and, sometimes, FEC and liveweight or BCS information to facilitate this. D, I, K and L stated that they were prepared to take a slightly laxer approach to parasite control of their replacement ewe lambs compared to the non-replacements, so they could identify those replacements that appeared to lack "resilience" to parasites and cull them.

M purchased and finished many lambs each year and aimed to only have a sound quarantine protocol for incoming lambs and then ideally administer no further treatments beyond that. Their quarantine protocol involved treating with a derquantel-abamectin combination AHC (Startect; Zoetis, Parsippany, NJ, USA; 1 mL/5 kg) on arrival and holding them on a gravel standoff area for 24 hours with provision of hay and water, before grazing them for 2 days on permanent pasture perceived to be contaminated with parasite larvae, and then moving them to a kale (*Brassica oleracea*) crop. Any further lamb treatment decisions were based on monitoring including FEC.

All participants implemented a range of non-chemical parasite control methods to varying degrees (Table 3). Those that were most used were feeding livestock well and cross-grazing with either alternate species or adult animals of the same species.

Feeding and high grazing residuals: All participants put a heavy emphasis on feeding their sheep well (Table 3) and keeping them in good condition and considered this an important aspect of their parasite control. For example, K commented that "a well-fed

Table 3. Summary of the level of use^a of non-chemical nematode parasite control methods in a group of 13 New Zealand sheep farmers identified as low users of anthelmintic (AHC) and enrolled in a study to investigate the personal drivers and sources of information for this approach and the gastro-intestinal parasite control methods employed.

Farm ID	Non-chemical nematode parasite control methods					
	Feeding	Cross-grazing	High post-grazing residuals	Crops or alternative forages	Use parasite-resistant maternal-breed rams	Cull replacements perceived to be “wormy” after late-autumn
A	High	High	Moderate	Low	None	Low
B	High	Moderate	Moderate	Not used	Low	High
C	High	High	High	Low	High	Low
D	High	High	High	Low	High	High
E	High	Moderate	Moderate	Not used	NA	NA
F	High	Moderate	High	Not used	High	Low
G	High	High	Moderate	Not used	High	Low
H	High	Moderate	High	Low	None	Low
I	High	High	High	Low	Low	High
J	High	Moderate	Moderate	Not used	High	High
K	High	High	Moderate	Low	High	High
L	High	High	Moderate	High	Low	High
M	High	High	High	High	NA	NA

^aLevel of use (high, moderate, low, not used) was determined by the authors based on systematic analysis of interview transcripts. NA = not applicable.

animal has less animal health challenges than a less fed one” while M believed that good nutrition assisted sheep to “out compete the [parasite] burden”.

High post-grazing residuals were recognised as important to ensure good nutrition and for reducing the exposure to parasite larvae. For lambs, 1,400–1,500 kg DM/ha was frequently quoted as being the minimum post-grazing residual that participants aimed for. Some participants described the advantages of a rotational grazing regime to ensure stock are well-fed and that higher post-grazing residuals are maintained.

Cross-grazing: All participants utilised cross-grazing, either with cattle or with adult ewes to maintain pasture quality and remove parasite larvae and placed a moderate to high emphasis on this for parasite control. C and G had substantially reduced their AHC use over the previous 3–4 years following a diagnosis of AR in their sheep flocks, and largely attributed cross-grazing, as well as improved flock nutrition, to enabling this change. For most, the system of cross-grazing appeared to be planned in a relatively *ad hoc* manner, but C and D had specifically developed a semi-structured cross-grazing system with a focus on parasite control.

In general, participants aimed to graze lambs on high levels of pasture cover and allow them to have the “best pick” of the available feed and then follow them with other stock classes. This was frequently young cattle followed by either adult ewes or older cattle. Some participants also emphasised the importance of not always using the same area of land for grazing lambs after weaning, to reduce the likelihood of those areas getting highly contaminated with parasite larvae.

Crops or alternative forages: Overall, there was a low emphasis on the use of crops or alternative forages for parasite control (Table 3). All participants primarily grazed their sheep on permanent pasture and only L

and M specifically used crops as part of their parasite management strategy. Both used forage rape (*B. napus*) and/or kale as they felt these would be the most effective for parasite control due to the crops’ growth habit. Six participants used crops or alternative forages occasionally or regularly, primarily for matching feed supply and demand and/or achieving high animal growth rates, although they recognised their potential for parasite control and reduced AHC inputs to sheep when on these forages. Five did not use them at all, primarily citing cost as the main reason for not doing so.

Genetics for parasite resistance: Eleven participants bred their own ewe lamb replacements with variation in their use of genetics for parasite resistance (Table 3). Three participants bred pedigree rams with a focus on parasite resistance, of whom two objectively measured changes using the WormFEC system (Sheep Improvement Ltd.; Anonymous 2023b). Three participants purchased rams from pedigree flocks who breed for parasite resistance, and this was an important selection criterion for them, but they had no objective measures of changes in genetic resistance in their flock. Three purchased rams from pedigree flocks who breed for parasite resistance, but this was not a consideration for them when selecting which rams to buy, while two did not purchase rams from flocks who breed for parasite resistance.

Culling replacements perceived to be “wormy” from late autumn: Six participants stated that from late autumn they had a policy of culling replacement ewe lambs that they judged to have high parasite burdens (“wormy”) based on perceived poor thrift and/or diarrhoea (Table 3), but no objective measures were used to assess parasite burdens in these animals.

Other parasite control approaches: Refugia was not a specific focus of the study, so this is not a comprehensive review of the participants’ use of, or attitudes

towards, refugia, but it does provide some insights and suggests some confusion regarding the concept and implementation of refugia. Participants G and H stated that they “don’t do refugia”, even though it was apparent during the interview that they did provide refugia through various means. However, they appeared to believe that refugia could only be achieved by leaving 10% of lambs untreated and were reluctant to do this. The concept of leaving some lambs untreated was frequently mentioned by the other participants although only C regularly used this option. Amongst the remaining participants, the most commonly described methods that would result in refugia were ensuring that AHC treatment intervals were not less than 28 days and utilising untreated adult ewes.

Most participants aimed to sell all non-replacement lambs by mid-March to mid-April either to slaughter or to other farmers. This was in part to prioritise winter feed to their ewe flock, but they also recognised the benefits for parasite control by reducing the worm challenge. Some stated that they were more rigorous with their AHC treatments for non-replacement lambs compared to replacements, so that their growth rates were not compromised, and they could sell them earlier.

Participants D, K and M discussed or alluded to targeted selective treatment as a potential means to reduce AHC use, but none were using it due to either a lack of individual animal identification or the time and effort required to implement it. Participant D had introduced dung beetles onto their farm, but this was with the objective of improving soil health rather than any focus on parasite control.

Theme 7. Participants’ understanding of parasite epidemiology and control

The participants’ understanding of parasite life cycles and basic parasite epidemiology appeared to range from sound to excellent. Based on their practices and narrative, it appeared that the key focus for their parasite control methods was reducing the exposure of sheep, particularly young sheep, to nematode larvae and integrating monitoring, non-chemical control methods and AHC to achieve this, for example:

I think what probably makes [our reduced AHC use system] work is around that observation. But it’s also around being aware that it could fall to bits. [It’s important to] know they are fed and making sure that you integrate all classes of stock and having the right classes of stock... we don’t use a lot of [AHC, but] it’s around making sure that when you do use them they are used at the right time, but not too late, that you haven’t put a heap of worms all around your farm. That’s probably the biggest thing we’re trying to avoid, is having a heap of wormy animals [causing a] wormy farm. (I)

However, some appeared to be prepared to accept some degree of production loss in some stock classes at some times to meet their goal of farming with reduced AHC use. This ranged from culling ewes or replacement ewe lambs that they perceived to be “wormy” rather than giving them AHC treatment, to accepting that occasionally the growth rates of lambs might be compromised, for example:

[There was] that one mob that got to 1,100 [eggs per gram], we might have lost ... some growth ... But in the scheme of the whole thing and being able to still be [farming] in 50 years’ time, [it’s a] price you have to pay sometimes. (M)

When asked if they had contingency plans if there was an apparent failure in worm control, all participants expressed confidence in their “stockmanship” to quickly detect issues and stated that they would administer AHC to affected sheep.

Despite their desire to reduce AHC use, many participants also expressed an element of pragmatism whereby due to logistics, timelines and workload, AHC were sometimes used when they were potentially unnecessary.

Discussion

This study analysed the information from interviews with 13 sheep farming participants who farmed with reduced AHC use, to explore their motivations for, attitudes towards and perceptions of the impacts of this choice and the nematode parasite control practices they used in pursuing it. The main findings were that a diagnosis of AR, or concerns about AR developing, were major motivators to reduce AHC use, a range of parasite information sources and decision-making processes were used, and perceptions of the impacts of reduced AHC use were positive although detailed information on financial impacts were not available. Regarding nematode parasite control methods, heavy emphasis was placed on monitoring using subjective criteria and where more objective criteria were used, primarily FEC, these were often used in an *ad hoc* manner. Feeding stock well and using cross-grazing methods were the most used non-chemical methods.

There is limited information on what constitutes “typical” AHC use on New Zealand sheep farms, if it in fact exists, and the most recent data available are almost 20 years old (Lawrence *et al.* 2007). Therefore, this study’s definition of “reduced” AHC use must be interpreted with caution. The methodology used, which included mapping all AHC use on a calendar and a semi-structured interview with the ability to use follow-up questions, provides some confidence that the participants’ stated AHC use was accurate. However, records on the volume of AHC purchased or administered were not used to cross-check and it

is possible that some participants may have understated their AHC use.

All previously published studies on AHC use and parasite control in New Zealand sheep flocks have been based on questionnaires with a limited range of possible responses to each question and quantitative analysis of the data (Kettle *et al.* 1981, 1982; Brunsdon *et al.* 1983; Macchi *et al.* 1999; Sharma *et al.* 2005; Lawrence *et al.* 2007). The advantage of such an approach is that it is possible to survey a large random sample of farmers. However, the wording of questions and possible responses can limit participants' opportunity to share their experiences and practices, and this approach cannot capture the detail of farmers' parasite management practices or explore their motivations or attitudes. The methodology used for the present study limited the number of participants but allowed for a broader and deeper range of responses. However, a comprehensive understanding of participants' underlying attitudes and beliefs would require a detailed follow-up interview.

The participants in this study were located throughout New Zealand, operated a range of different farming systems, and had varied farming philosophies. As such, our findings suggest there is no particular type of farmer who chooses to farm with reduced AHC use and farming with reduced AHC can be compatible with, or indeed contribute to, achieving a range of different objectives. However, consistent with overseas studies (Cornelius *et al.* 2015; Jack *et al.* 2017), the perceived threat or the reality of AR was a key motivator for participants to reduce AHC use. Therefore, it is probable that increasing numbers of farmers will seek to re-evaluate their parasite control practices as AR becomes more prevalent. This study and others (e.g. Lawrence *et al.* 2007; Jack *et al.* 2017; Charlier *et al.* 2022) have identified that farmers consider veterinarians as a very important source of parasite information, indicating that veterinarians will have an important role in assisting farmers with these changes. The limited availability of veterinarians with the specialised knowledge needed to advise farmers on parasite management was identified as a challenge by both the participants we interviewed and in the literature (Kaler and Green 2013; Jack *et al.* 2017; Charlier *et al.* 2022).

While only a small number of participants were included in this study, they were purposively selected and are non-typical in that they have chosen to manage parasites in a manner that probably wouldn't be considered usual for New Zealand. Due to the way the participants were identified, it is likely there was a selection bias towards those that engage closely with vets and/or other advisors. However, this non-typical cohort of individuals utilised a range of parasite information sources and had variable approaches to decision-making, similar to those

described by international researchers who surveyed randomly selected farmers (e.g. Morgan *et al.* 2012; Moore *et al.* 2016; Colvin *et al.* 2021). However, in contrast to those studies, the participants in the present study did not identify other farmers as useful sources of information, which likely reflects the general lack of reduced use of AHC on New Zealand sheep farms. It is clear that no one form of engagement will suit or reach all farmers, regardless of their motivations for choosing to engage with it. As such, it will continue to be important that future extension and engagement initiatives are delivered in a range of ways to reach farmers with different farming philosophies, learning styles, information preferences and decision-making practices, rather than using one approach in isolation (Jack *et al.* 2017; Colvin *et al.* 2021).

Although none of the participants could provide detailed information regarding the financial impacts of farming with reduced AHC use, international research suggests that low-AHC systems could be cost-neutral or potentially more profitable. For example, Learmount *et al.* (2016) undertook a 3-year study in the UK whereby eight farms implemented the UK guidelines for the sustainable control of parasites in sheep (SCOPS) and eight farms maintained their existing parasite management regime. They showed a significant reduction in AHC use and potential economic benefits associated with reduced AHC and labour costs on the SCOPS farms (Learmount *et al.* 2016). A subsequent cost-benefit analysis reported that, overall, there was a benefit for medium (1,000 ewe) and large (1,900 ewe) farms for implementing the SCOPS guidelines (Learmount *et al.* 2018).

All participants identified monitoring as a key component of their parasite management, but for the majority the factors assessed were primarily subjective, encompassed by the term "stockmanship". Participants expressed confidence in their "stockmanship", but it was beyond the scope of this study to quantify the effectiveness of their monitoring, and it is therefore not possible to know whether their view of their ability matches the reality. "Stockmanship", and the processes behind using it to make decisions on AHC use, are likely to be particular to the individual and complex processes, based on knowledge, experience, and beliefs. However, most participants indicated that FEC were, or had in the past been, valuable in aligning subjective information with more objective measures of parasite burden. This suggests that FEC may have an important role in aiding sheep farmers to calibrate subjective monitoring criteria.

The non-chemical methods used by the participants for parasite control are well established (e.g. Southcott and Barger 1975; Leathwick *et al.* 2015; McAnulty and Cook 2019) and no novel non-chemical solutions for nematode parasite control were reported in this study. It was beyond the scope of this study to

determine the success of internal parasite control practices on participants' farms. However, if sheep farmers move away from more typical AHC use to reduced AHC use it is probable that a good understanding, and careful implementation, of non-chemical control methods will be important in facilitating this. There is likely a role for veterinarians with an understanding of farm systems, in conjunction with other experts, to provide expertise in this area (Dodunski 2022).

Some participants expressed or implied that they were prepared to accept some level of adverse production consequence in at least one sheep stock class to pursue their goal of reduced AHC use. This approach likely requires careful consideration of the probable risks and benefits associated with reduced drug use. The appetite for risk amongst the participants in the current study varied from those who appeared relatively risk averse through to those who were prepared to "push the boundaries". However, the focus on reducing AHC use was also balanced by an element of pragmatism whereby for convenience animals were sometimes treated even if it was not necessarily indicated. Farmers' decision-making around the use of animal health remedies, including AHC, is known to be complex and based on their circumstances, context, goals, and beliefs (Ritter *et al.* 2017; Bellet 2018). This complexity needs to be considered when working with individual farmers to adopt strategies for parasite control.

Of the 11 veterinarians or advisors across New Zealand who nominated potential participants, each could only identify one to five farmers who they knew to have reduced AHC use compared with other farmers in their area. This may suggest that the proportion of farmers implementing a reduced AHC approach to internal parasite management in New Zealand is low.

However, it is also possible that veterinarians and advisors have a limited knowledge of parasite control practices on many of their clients' farms. A study of 600 farmers in Great Britain and Ireland reported that 92% of farmers planned their own parasite management decisions while only 7% involved their veterinarian (Morgan *et al.* 2012). It is unknown whether this would be similar in New Zealand and a nationwide survey would be required to better characterise AHC use and parasite management practices on New Zealand sheep and beef farms.

In conclusion, AR was a key motivator for participants to reduce their AHC use, and they utilised a range of information sources, particularly veterinarians, and decision-making processes to inform their parasite management practices. Key parasite management practices utilised by participants were monitoring, primarily using subjective assessments, and an emphasis on feeding stock well and using cross-grazing methods.

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