Controlling nematode infections in sheep: application of HACCP

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Gastrointestinal nematode infection in sheep is a significant challenge for production with implications for animal health and welfare, and lamb growth. Flocks rely on the chemical control of worm burdens, but with the increasing challenge of anthelmintic resistance there is a necessity for farmers to uptake SCOPs (Sustainable Control of Parasites) guidance. Vets need to communicate practical strategies to farmers and suggest novel approaches that address these challenges so that holistic and sustainable parasite management can be achieved. This article examines the challenge of nematode infections and anthelmintic resistance and suggests how hazard analysis and critical control point (HACCP) application may facilitate a whole-flock strategy.

GASTROINTESTINAL nematode (GIN) infection and associated parasitic gastroenteritis (PGE) is arguably one of the biggest challenges for British sheep production, costing an estimated £84 million per annum to the industry (Nieuwhof and Bishop 2005). In sheep affected by PGE, gastrointestinal tract damage, protein or blood loss, and a costly immune response results in observable drops in daily live weight gain (DLWG) and scouring (Fig 1), which is also known as dagging and measured using a dag scoring system from 1 (no faecal soiling) to 5 (faecal soiling covering tail, breech and legs). In the case of Haemonchus contortus, anaemia and increased mortality are also seen (Coop and others 1982, Coop and Kyriazakis 1999, Sargison 2009, Mavrot and others 2015).

The cost of exposure was demonstrated by Coop and others (1982), where increasing exposure to infective larvae resulted in slowed growth rates that could not be mitigated by anthelmintic treatment (Fig 2). Lambs in five groups were exposed to zero (ad libitum control group [ALC]), 1000 (Group 1), 3000 (Group 2), 5000 (Group 3) and 5000 (Group 4) infective larvae of Teladorsagia circumcincta. Lambs in Group 4 received an effective anthelmintic treatment every 21 days. Although the performance of Group 4 was better than Group 3, the lambs did not achieve the DLWG performance of the ALC, despite anthelmintic treatment, and their performance was similar to that of Group 2. This highlights the importance of avoiding exposing sheep to high levels of infection, and not just relying on regular anthelmintic treatment in situ.

Although infected lambs may still achieve 110 g/day growth (Kenyon and others 2009) this is below target growth rates of 250 g/day (AHDB 2014) and results in delays to finishing time (Miller and others 2012), delayed onset of puberty in breeding ewe lambs and, in some cases, permanent stunting. Furthermore, PGE can result in a 10.4 per cent reduction in carcase value (Miller and others 2012). Ineffective treatment of PGE has been demonstrated to result in 60 to 100 per cent drops in growth relative to effectively treated animals (Abbott and others 1986).

Historically, anthelmintics have played a central role in the management of PGE (Miller and others 2012). However, effective control now requires a more thoughtful approach in the face of multiple challenges. First and foremost, dependency on anthelmintic products and their misuse has led to the development of anthelmintic resistance. It

![Fig 1: Ewe with signs of scouring. Scouring and increased dag score can indicate parasitic gastroenteritis, but are undesirable as monitoring tools because affected individuals are likely to have significant damage to their gastrointestinal tract, constituting a welfare issue, and delayed finishing times, incurring a large cost to the flock.](image1)

![Fig 2: Impact of gastrointestinal nematode infection on cumulative live weight gain (adapted from Coop and others 1982).](image2)

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is hoped that the headline figures showing extremely high prevalence of anthelmintic resistance given in Box 1 will drive home the message that this is not simply something that happens to ‘other farmers’; anthelmintic resistance is widespread and, despite the fact that it may not be causing visible reductions in productivity on most farms, sustainable use of anthelmintics is required to preserve their efficacy and prevent deterioration to the point where performance and welfare are compromised.

Second, there are broader environmental implications of PGE and anthelmintic resistance beyond the farm, which are becoming increasingly important to both producers and consumers as environmental awareness increases. Sheep production is responsible for an estimated 52 per cent of all agricultural emissions in Scotland, and PGE was identified as one of the ‘top three’ diseases with a significant impact on greenhouse gas emissions in the livestock sector, based on its impact on growth and feed conversion rates (Bartley and others 2016). In addition, the impact of anthelmintics on dung fauna and knock-on effects at higher trophic levels is well documented (Floate and others 2005). Repeated ineffective treatments, either due to user error or exacerbated by anthelmintic resistance, have the potential to contribute to increased environmental impacts associated with PGE control.

**HACCP: risk-based PGE management planning**

Overall, these challenges highlight the importance of growth-rate performance as a key driver of environmentally efficient production, and the necessity for PGE management solutions to be practical and accessible by commercial sheep producers. Risk assessment and management planning (RAMP) approaches to disease control are commonly used to identify disease challenge and risks retrospectively, and implement corrective action (McAloon and others 2015). However, RAMP is largely based on recollection by farmers of the risks to their production process, is often confined to a single temporal point of assessment (ie, undertaking an annual review depends on good record-keeping of mortality and growth rates) and is typically applied after disease becomes an issue. Therefore, the conditions are often not in place for effective application of RAMP to sustainably prevent the effects of PGE on performance and welfare.

**Box 1: Anthelmintic resistance in sheep in the UK**

In a study by Morgan and others (2012), 10 per cent of farmers surveyed felt there was evidence of failure of anthelmintic efficacy in their flocks, but this is likely to be a gross underestimate. Resistance is currently defined as a post-treatment faecal egg count (FEC) reduction of less than 95 per cent (see Coles and others 1992 for protocol), but clinically obvious failure (ie, poor resolution of clinical signs after treatment) will only become apparent when treatment efficacy is less than 85 per cent (Abbott and others 2012), by which point anthelmintic performance is severely compromised, with little chance of preserving the useful efficacy of that drug class. The true prevalence of anthelmintic resistance in the UK is unknown, but some regional surveys are available (Table 1).

**Table 1: Percentage of farms with evidence of anthelmintic resistance**

| Anthelmintic | Wales Autumn/ Winter 2014* | Wales Spring/ Summer 2015* | Devon 2013** |
|-------------|-----------------------------|----------------------------|--------------|
| 1-BZ (benzimidazoles) | 89 per cent (n=25) | 100 per cent (n=30) | 96 per cent (n=24) |
| 2-LV (levamisole) | 68 per cent (n=19) | 73 per cent (n=22) | 60 per cent (n=15) |
| 3-Macrocyclic lactone (ML)/VM (ivermectin) | 25 per cent (n=7) | 70 per cent (n=21) | 67 per cent (n=18) |
| 3-ML MOX (moxidectin) | 18 per cent (n=5) | 30 per cent (n=9) | n/a |
| Multiple drug resistance | 68 per cent (n=19) | 90 per cent (n=27) | 84 per cent (n=21) |

* Thomas and others 2015  ** Glover and others 2017

Worryingly, multiple drug resistance was detected on the majority of farms surveyed in Devon (Glover and others 2017) and Wales (Thomas and others 2015). Overall, 19 per cent of Welsh flocks surveyed had evidence of resistance to 1-BZ, 2-LV and both ivermectin and moxidectin within the 3-ML group. Ivermectin and moxidectin do overlap in mechanism of action but resistance mechanisms are not entirely homogenous between the two, hence resistance to each is considered separately (Prichard and others 2012). There have been documented cases of monepantel resistance in New Zealand (Scott and others 2013) and the Netherlands (van den Brom and others 2015) and the first case of monepantel resistance was reported in the UK in 2018 (Hamer and others 2018).

**Box 2: HACCP principles and application guidelines (adapted from FDA 1997)**

1. Conduct a hazard analysis
   a. Define the production process; for example, lamb production from tupping to leaving the farm.
   b. Define which hazard you are trying to avoid and mitigate, such as drops in daily live weight gain (DLWG) due to parasitic gastroenteritis (PGE).

2. Determine the critical control points (CCPs); that is, the opportunities to influence or protect DLWG through minimising exposure to gastrointestinal nematode (GIN) infection. CCPs are steps at which control can be applied. This is essential to prevent or eliminate a hazard or reduce it to an acceptable level. CCP decision trees should be developed to restore deviations from predetermined ranges to within normal ‘safe’ parameters.

3. Establish a framework for:
   a. Critical limits (ie, what is acceptable for DLWG?),
   b. Monitoring procedures (ie, how are you going to establish that infection is present at levels that cause deviation from DLWG targets?),
   c. Record keeping and documentation procedures.

4. Establish corrective actions; that is, how are you going to mitigate infection impacts if present?

   There are four key areas (GAME strategy) which could be addressed to minimise the impact of disease:
   - G - general health and genetics
   - A - avoidance
   - M - monitoring
   - E - effective and efficacious treatment

Corrective actions should take into account the existing flock management calendar and any flexibility within this to ensure actions are practical.

5. Establish verification procedures; that is, how are you going to evaluate that what you have done is working? These should be activities, other than monitoring, that determine the validity of the HACCP plan and ensure that the system is operating according to the plan.
manage anthelmintic resistance. Hazard analysis and critical control points (HACCP) is an alternative risk-based and process-driven approach which involves proactive monitoring with defined end points (Box 2).

Using HACCP in practice

HACCP was developed for use in food safety but has been adapted for primary production such as to monitor for bovine Johne’s disease (McAlonan and others 2015), to control bovine mastitis (Noordhuizen and Franken 1999) or bovine lameness (Bell and others 2009), for management of trematodes in aquaculture (Clausen and others 2012) and good farming practices should be implemented to control tapeworms in sheep (Gascoigne and Crilly 2014) and to monitor ovine abortion (Crilly and Gascoigne 2016). In this article, we apply the HACCP model to the process of lamb production with the end goal of minimising losses in DLWG through improved control of PGE (Box 2, Fig 3). The hazard in this case is ‘exposure to worms’ at a level sufficient to cause slowing of DLWG.

Developing a PGE management plan or discussing improved PGE management with a client using the HACCP model is a stepwise process which aids understanding of the production process, points to where the risk of exposure to infection can be manipulated (critical control points [CCPs]), and where sustainable corrective actions at these CCPs – using the GAME strategy described below – can be implemented (Box 2). Sustainable Control of Parasites in Sheep (SCOPS) guidelines (Abbott and others 2012) and good farming practices should be the cornerstone of corrective actions at CCPs. When prevention cannot be achieved, corrective measures will need to be introduced and this may necessitate revising flock health plans. The GAME approach is based on an adaptation of the four founding SCOPS principles of PGE management:

- Making sure that any treatment is fully effective;
- Reducing reliance on anthelmintics using management and monitoring;
- Quantifying and minimising selection for resistance when treating;
- Best practice when administering treatment.

Data and record keeping on farm (ie, keeping records in a medicines book for meat withdrawal purposes and sheep movements) is a prerequisite. However, vets should think outside the box for performance data; for example, look at the finishing profile of lambs – what is the average number of days to finish? This may help estimate overall DLWGs and assess overall efficacy of the HACCP process.

Corrective actions: GAME

Having identified practical CCPs, there are four key areas which could be addressed to minimise the impact of disease. These four areas, if sequentially considered, place administering anthelmintics as the final option for management, after making maximum use of the alternatives.

G – General health and genetics

Poor general health and nutrition of the flock will undermine immune status, increasing susceptibility to disease. Trace element status, nutritional status and endemic diseases will contribute towards increased worm egg shedding (Coop and Holmes 1996, Wallace and others 2009, Sargison and others 2007). Dietary supplementation with metabolisable protein before lambing has been shown to dampen periparturient worm egg shedding in ewes (Houdijk and others 2000). The SAC (2010) reported that providing 100g digestible undegradable protein (DUP) per lamb in late pregnancy significantly reduced worm egg shedding in the periparturient period and enhanced ongoing lactational performance, that is, enhancing lamb DLWG. The use of bioactive forages to reduce worm egg counts in ewes has been explored with mixed results (Hoste and others 2006).

Genetically resilient and/or resistant sheep may also have enhanced ability to perform under worm challenge (Bisset and others 2001, Jackson and others 2009). Resistant sheep control worm egg production by mounting an immune response, whereas resilient sheep might have a degree of tolerance to PGE, growing in the face of high burdens, but continue to shed eggs (Jackson and others 2009). Such sheep could potentially be identified and

### Table: HACCP application to a flock health calendar

| Month | Scanning of flock | Pre-lambing management of ewes (housing/ outdoors) | Critical control point (CCP) periparturient (risk in ewes) | Lambing of flock | CCP: grazing infection of lambs | Topping of flock | CCP: pasture risk assessment |
|-------|------------------|-----------------------------------------------|-------------------------------------------------|----------------|---------------------------------|----------------|------------------------------|
| Jan   |                  |                                               | General health, trace element |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Feb   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Mar   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Apr   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| May   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| June  |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Jul   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Aug   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Sep   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Oct   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Nov   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |
| Dec   |                  |                                               | Low risk turnout pasturing |                   | CCP: grazing infection of lambs |                   | CCP: pasture risk assessment |

Fig 3: HACCP application to a flock health calendar. Gastrointestinal nematode infection, resulting in reduced weight gain, was identified as a hazard, and the production system, with key management events, was defined on the calendar. A system for record keeping and monitoring was put in place. Critical control points (CCPs) (green boxes) were identified; these are points at which the hazard can be eliminated, prevented or reduced to acceptable levels. For each CCP, corrective actions are identified using the GAME strategy (see Box 2). Finally, options to verify control (orange boxes) throughout the year and at the end of the year were identified and put in place.
selected for breeding under conditions of high infection pressure, either for resilience using DLWG-estimated breeding values (EBVs) and breeding policies with positive growth despite high infection pressure, or for resistance using faecal egg count (FEC) EBVs to identify those individuals shedding fewer worm eggs or IgA EBVs (Shaw and others 2012). Over time, selecting for resistance could reduce the susceptibility of the flock to PGE while reducing pasteure contamination and ongoing exposure to infection, thus reducing the need to use an anthelmintic to maintain growth rates.

The role of vaccination of sheep against GIN is under development, with a commercially available vaccine for Haemonchus contortus available in Australia and South Africa (Barbervax; Wormvax Australia) and published trial work supporting the efficacy of subunit vaccines to reduce ewe shedding of Teladorsagia circumcincta eggs at the time of lambing (Nisbet and others 2013). However, it is unlikely that these vaccines will achieve a greater than 90 per cent reduction in egg counts and, as a consequence, whole-flock strategies are still necessary (Matthews and others 2016).

A – Avoidance
Understanding the epidemiology of infection and development of immunity is essential for avoidance-based strategies on farm, which rely on grazing high-risk animals on the lowest risk grazing and forward planning to enable ongoing avoidance of such pastures. Strongyle eggs can survive on pasture for more than 12 months (Rose 1961). Pre-existing worm burdens should be considered when assigning risk to pastures. Knowing where previous high-risk shedding classes of stock have been grazed enables risk to be assigned to pastures (Fig 4).

Recording where and when strongyle burdens are greatest on farm by monitoring movements enables avoidance of infection (Box 3). Grazing vulnerable lambs on high-risk pasture will undermine productivity and growth, necessitating high-drench use for production to continue. FECs and weather-based disease alerts can also feed into pasture-mapping and risk monitoring (Fig 5, Box 3). For example, pastures assessed as high risk based on contamination by growing lambs shedding Nematodirus eggs (identified in FECs) the previous year can be avoided when Nematodirus risk is predicted to be highest and lambs are most vulnerable to infection.

Avoidance strategies also extend to buying in anthelmintic-resistant GINs with new stock. Morgan and others (2012) found that 35 per cent of flocks surveyed were buying in sheep, but only 17 per cent were quarantined as a standard procedure, and in many cases this was done ineffectively. Treatment with a new derivative and a sheep scab control is ‘gold standard’ quarantine practice (SCOPS 2016). It is imperative that all advisers are consistent in delivery of this advice. Worryingly, total new derivative use in 2015/2016 accounted for 1 per cent of total drench use (SCOPS 2017), a fraction of the likely number of sheep moving premises in the same period.

M – Monitoring
Having planned a strategy based on having high-risk lambs on the lowest risk category of grazing available (Fig 4, Box 3), ongoing monitoring and review of avoidance strategies is essential to evaluate efficacy, ongoing performance and to establish if treatment is necessary.

Monitoring DLWG (Fig 6) in lambs, although not very specific for parasitic disease, is by far the most sensitive indicator of PGE-related impact. If performed regularly it will identify early drops in performance before significant damage to the gut lining and irreversible stunting has occurred. The disadvantages to such a method include the potential high labour inputs, especially if labour-saving technology is not used for weighing and data recording. Regular monitoring will identify drops in group performance as well as in individuals, and generate opportunities for targeted selective treatment protocols, further reducing overall drench usage (Kenyon and others 2009, Shar and others 2009, Busin and others 2014). A review of key phases of growth is described by Gascoigne and Lovatt (2015).

When used alongside other diagnostic tools, such as FECs (Fig 7), the specificity of DLWG monitoring will be improved, which may highlight other challenges for performance
Box 3: Pasture avoidance for parasite management

Understanding where high levels of infection are found on the farm permits grazing rotations to be designed to avoid parasite burdens. Risk assessments should be performed periodically throughout the production year. Highest risk animals (i.e., fast-growing lambs) should be placed on lowest risk pastures available.

Pastures can be referred to as high-risk, medium-risk or low-risk pastures and practical application could be assigning risks to ordnance surveys maps of the farm at flock planning meetings (Fig A).

The pasture risk assessment approach can be extended by incorporating faecal egg counts (FECs) to assess the magnitude of contamination, and therefore risk, on each pasture. These risk assessments also evaluate the scale of the on-pasture refugia population which should highlight and emphasise the importance and risks associated with dose and move (Abbott and others 2012) and be used to adjust treatment schedules where appropriate. For example, leaving a proportion of the flock untreated is especially important if they are to be moved to low-risk pasture to ensure a population of worms in refugia within the sheep are available to mitigate the lack of significant on-pasture refugia. Furthermore, mathematical models predicting gastrointestinal nematode population dynamics and risk of infection, such as the Nematodirus forecast (Fig 5) (Gethings and others 2015, www.scops.org.uk) and Haemonchus contortus/Teladorsagia circumcincta models (Rose and others 2015) can be integrated with the pasture-mapping exercise and regularly reviewed in conjunction with FECs and grazing history to inform pasture-level risk assessments.

Such as nutritional deficits and underlying trace element deficiencies. FECs give an indication of burden and can be used regularly to monitor worm egg shedding throughout the growing season to target treatments, evaluate anthelmintic efficacy and record pasture contamination. They are easy to perform and can be undertaken on farm using technical solutions, such as FecPak (Techion Group), or processed at the veterinary practice. However, sample collection and handling techniques are critically important to generate robust, repeatable results (Morgan and others 2005, Abbott and others 2012, Crilly and Sargison 2015) and correct interpretation requires engagement with a veterinarian or qualified adviser. FECs will vary across groups and pastures, and care should be taken when applying single FEC counts across an age category or a whole farming enterprise. Also, it is important to note that there will be a delay between infection, gut inflammation and faecal egg counts.
and egg production, and prepatent disease costs will be missed by FECs (e.g., in nematodiorasis).

Monitoring can incorporate clinical signs (e.g., dag scoring [Fig 1]), evidence of illthrift, and visible drops in body score in lambs. We suggest that it is undesirable to rely on clinical monitoring alone because of high levels of subjectivity and substantial drops in DLWG before such signs are recognised. Relying solely on clinical indicators is likely to be highly inefficient with both economic and environmental costs accumulating in the interim, leading to increased days to finishing and, in instances of severe disease burdens, mortality (Sargison 2009). Evidence of clinical disease indicates failure of the checks and balances already in place.

E – Effective and efficacious treatment

Once PGE has been confirmed in a group, despite avoidance, monitoring and attention to general health, targeted treatment is warranted. Treatments should adhere to the SCOPS principles (Abbott and others 2012) and farmers should be made aware of the 5 Rs for effective treatment:

- Right product;
- Right animal;
- Right time;
- Right dose;
- Right way.

Choosing the right product includes using a product that is effective (established through regular testing for anthelmintic resistance) and suitable for the parasitic burden of the flock. Treating the right animal can include, for example, avoiding unnecessary treatment of ewes and, by extension, targeted selective treatment of lambs based on DLWG and/or FECs. Treating at the right time includes monitoring to identify the optimal timing for treatment. Administering the right dose rate includes dosing to the correct weight of the individual (or heaviest in the group) and calibrating equipment. Administering treatment in the right way includes the correct drenching technique or injection site.

Drench use can be reduced further by using targeted selective treatments; that is, treating those individuals with evidence of disease such as drops in DLWG, without having a negative effect on overall performance (Kenyon and others 2009, Busin and others 2014, Learmount and others 2015). This is a significant change in rhetoric for many farmers and vets, deviating as it does from the need for whole-group sanitary measures against many other diseases, and may be impractical for some flocks to achieve without accurate record keeping.

Given the high prevalence of anthelmintic resistance (Box 1), the anthelmintic resistance status of a farm should be checked at intervals to ensure that only efficacious anthelmintic classes of drugs are used. This can be assessed using pre- and post-treatment FECs and checking for a greater than 95 per cent reduction in eggs, or by checking post-drench samples for the presence of fewer than 50 eggs per g. However, the limitation of the latter method is the inability to assess percentage reduction and reliance on a high pretreatment FEC. Nevertheless, routine post-drench checks should be encouraged, even if the pretreatment FEC is unknown. Readers also need to be aware that resistance profiles may vary between strongyle species on farm and therefore within season due to the seasonal succession of nematode species within the hosts (Thomas and others 2015) and even between areas on a farm. Speciation and repetition will enable practitioners to decipher if variation occurs between different times of year, and equally if drenches retain efficacy depending on species. This understanding should be built up over time, by integrating drench checks into routine flock health monitoring.

Equally, the new derivatives monepantel (Zolvix oral solution for sheep; Elanco Animal Health) and deraquenat/abamectin (Startect dual active oral solution for sheep; Zoetis Animal Health) have a role to play as mid- to late-season knock-out/break-dose drenches. Every time any anthelmintic is used on an animal, the gut strongyle population is skewed so that resistant worms survive to contaminate pasture. Over the season and as multiple drenches are used there will be a selection pressure for and accumulation of the resistant population. Mid- to late-season treatment of remaining lambs on farm aims to remove these worms, preventing continued pasture contamination by resistant strains. At that time of year, there is likely to be a substantial on-pasture refugia, hence reducing the risk of development of new derivative resistance due to dilution of any resistant strains that have developed. In a scenario where a low-drench dependency management system has been developed and a targeted minority of lambs have been treated, break-dosing/mid-late season knock-out drenching may not be necessary, but where sequential treatments have been used, modelling has demonstrated that this targeted treatment can slow resistance (Leathwick and Hosking 2009). Combination anthelmintics may also slow the development of resistance if the pre-existing levels of resistance are low and there are sufficient parasites in refugia (Bartram and others 2012, Leathwick and others 2012).

Summary

PGE and anthelmintic-resistant GIN are a significant threat to the productivity of commercial sheep flocks in the UK. This risk is rapidly escalating and veterinary surgeons have a central role to play in its management.

The necessity for engagement is emphasised by other bodies in the sector, such as the National Sheep Association and the Farm Animal Welfare Council (FAWC). Given the broader implications of anthelmintic resistance, FAWC’s 2016 report stresses the importance of knowledge sharing and improving performance (FAWC 2016).

As flock planning advisers we need to be clear about the aims of management plans on farm (i.e., usually efficient and rapid growth of lambs on farm), and PGE is a significant threat to that. We have described a framework for flock-wide discussion of PGE and key strategies which should be used at each CCP, highlighting that chemical control should be used only after a series of avoidance strategies have been put in place, monitored and treatment found to be necessary.

The veterinary surgeon’s ability to understand and deal with this integral limiter of performance by using a flock-wide approach including nutrition, infectious disease, trace element status, best practice and evidence-based medicine places them in a unique position to facilitate management of PGE. The challenge for many practitioners is the initial development of a proactive working relationship, but the evidence for necessity is compelling and the threat of uncontrolled anthelmintic resistance is rapidly becoming a reality.
Declaraton of conflict of interest

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In Practice | October 2018 | Volume 40 | 334-347
Farm Animals

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Self-assessment: Controlling nematode infections in sheep: application of HACCP

1. Parasitic gastroenteritis has been demonstrated to cause losses in carcase value of up to which per cent?
   a. 2.4
   b. 5.4
   c. 10.4

2. What does HACCP stand for?

3. Which of the following monitoring systems will usually enable the earliest detection of parasite burden requiring treatment?
   a. Daily live weight gain
   b. Faecal egg counts
   c. Faecal soiling and clinical signs

4. In the faecal egg count reduction test study in the south west (Glover and others 2017), what percentage of flocks had evidence of multi-antibiotic resistance?
   a. 64
   b. 84
   c. 94

5. According to the AHDB pasture risk assessment tool, which of the following has the lowest risk category?
   a. In Spring, land which had store lambs on in the autumn
   b. In Spring, land which had lambs on last summer, but dry ewes in the autumn
   c. In Autumn, pasture which has been rested since weaning but had lambs on it at turnout

Answers: c, Hazard analysis and critical control points, a, b, b

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