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Equine de-worming: a consensus on current best practice

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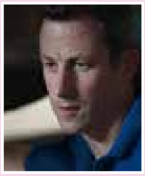

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David is a director at Rainbow Equine Hospital, North Yorkshire and splits his time between leading the internal medicine and critical care services and running the referral laboratory. Since graduating from The University of Bristol in 2001 he has worked in universities in both the UK and Australia, but has spent most of his career in private equine practice in the UK. He is actively involved in all fields of equine medicine and has published on a range of topics. He has worked as a consultant for a number of pharmaceutical companies and CPD providers, some of whom have a commercial interest in parasitology (BOVA UK Ltd, Norbrook AH, Virbac). He holds the RCVS certificate in equine medicine and was awarded a masters degree from The University of Glasgow for research into equine lower airway disease. He is a diplomate of the European College of Equine Internal Medicine and is recognised as a specialist by The Royal College of Veterinary Surgeons.

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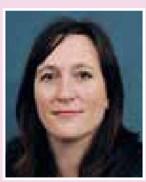

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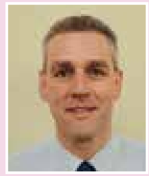
Jane is Professor of Molecular Veterinary Parasitology, University of Liverpool. Her primary research focus is on anthelmintic resistance in parasites of ruminants and horses. Over the last 20 years she has secured multiple grants to investigate key aspects in the biology of the equine parasites, their diagnosis and control and is academic lead for the University of Liverpool's equine parasitology diagnostic service, Diagnosteq. She has an extensive teaching portfolio at both undergraduate and postgraduate level and is a keen promoter of knowledge exchange to the equine community, promoting sustainable control practices.



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Bruce graduated from the University of Edinburgh as BSc (Veterinary Pathology) in 1983 and BVM&S with Distinction in 1985. After working for three years in mixed veterinary practice in Buckinghamshire, he returned to Edinburgh as the Horserace Betting Levy Board Resident in Equine Respiratory Diseases. He was awarded a PhD on equine asthma in 1992 and has continued in the Department of Veterinary Clinical Sciences ever since. He was awarded the Animal Health Trust's Veterinary Achievement Award in 2004. He is currently Professor of Equine Medicine and Head of the Equine Section at the University of Edinburgh. His research focuses on internal medicine, particularly equine pulmonary disease and equine grass sickness. No conflicts of interest to declare.

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Jacqui has worked in helminth research and education for over 25 years. Her group studies ruminant and equine nematodes, focussing on vaccines, diagnostics, drug resistance and developing/disseminating best practice strategies. She dedicates much of her time to disseminating information on sustainable worm control. She is technical advisor to the livestock industry group on sustainable worm control in cattle (COWS) and is editorial board member of several international research journals. In addition to membership of grant review and animal welfare committees, Jacqui holds a Ministerial appointment on the UK Veterinary Products Committee. In 2017, she was granted Fellowship of the Royal College of Veterinary Surgeons for Meritorious Contributions to Knowledge, and conferred Elsevier's International Journal for Parasitology Award. She is an RCVS Recognised Specialist in Veterinary Parasitology. She is Honorary Professor at the Royal (Dick) School of Veterinary Studies, University of Edinburgh.

Foreword

Despite increasing awareness within the veterinary profession and equine industry of the potential implications of anthelmintic resistance (AHR), there is a concern that insufficient measures are being taken to reduce its development and spread. This document was commissioned to provide veterinary surgeons with up to date information on worm control plans that will prevent clinical disease while minimising selection pressure for resistance. Recommendations were developed using an informal two-round Delphi process, considering published and unpublished research relating to equine parasite control using a roundtable forum and online discussion. Where research evidence was conflicting or absent, collective expert opinion, based on the experience of the group, was applied. The opinions expressed are the consensus of views expressed by the authors. Where agreement was not reached opposing views are presented such that readers can understand the arguments. The document is focused on the management of horses and ponies; while much of the information herein applies to donkeys, it is important to recognise that donkeys face major challenges with AHR, and further research is required before specific recommendations can be made with respect to this species. The expert group was organised by UK-Vet *Equine* and hosted by Moredun Research Institute with sponsorship from Virbac and additional support from The Horse Trust and vetPartners.

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Equine de-worming: a consensus on current best practice

Decades of regular and often indiscriminate administration of anthelmintics (AH) has compromised the efficacy of most, if not all, deworming products licensed for use in horses. How rapidly resistance will continue to develop and how this will affect equine welfare in future is unknown, but morbidity and mortality associated with helminth-associated disease are already common. The authors are unaware of any new class of equine AH under development, so those available currently have to be used judiciously, balancing the risk of disease in individuals with the sustained health of the population. A key concept in maintaining the efficacy of AH is maximising refugia; refugia being those parasites within a population that are not exposed to selection pressure by AH treatment. The progeny of parasites in refugia dilute the progeny of resistant parasites that survive treatment, hence slowing the process of selection for resistance.

Resistance in cyathostomins

The most recent assessments of anthelmintic resistance (AHR) in cyathostomins in the UK were published in 2013 and 2014, following investigations performed on livery yards in Scotland (Stratford et al, 2014a), Thoroughbred stud farms across England (Relf et al, 2014) and livery yards in Southern England (Lester et al, 2013a). At this time, there was evidence of resistance (assessed using a faecal egg count reduction test (FECRT)) to fenbendazole on every one of the 30 properties tested. Pyrantel resistance was identified on 70% of the stud farms and on 17% of the livery yards in England, but on none of the livery yards in Scotland. Some evidence of reduced efficacy of ivermectin was identified on one stud farm. Reduction in strongyle egg reappearance periods (ERP) following AH treatment are thought to be a marker of lowered sensitivity of a particular worm population to a given compound; a reduced strongyle ERP was identified for both ivermectin and moxidectin on all Thoroughbred stud farms where this analysis was undertaken (Relf et al, 2014). Reductions in strongyle ERP following moxidectin was reported in the UK as early as 2008 in Thoroughbreds (Dudeney et al, 2008) and 2005 in donkeys (Trawford et al, 2005). The degree to which AHR has increased in the UK between 2013 and 2019 is unknown; however, there have been further reports of reduced ERP following ivermectin (Molena et al, 2018) and moxidectin (Tzelos et al, 2017) treatment. Anecdotal reports suggest that reduced cyathostomin ERP following administration of ivermectin and moxidectin is common in the UK with the ERP commonly now half (4–6 weeks) what it was when these drugs were first licensed (ivermectin > 8 weeks, moxidectin >12 weeks), particularly in youngstock. A summary of the expected strongyle FECR and ERP in susceptible worm populations is presented in *Table 1*.

Abbreviatons

AH	anthelmintic(s)
AHR	anthelmintic resistance
EPG	eggs per gram
ERP	egg reappearance period
FEC	faecal egg count
FECR	faecal egg count reduction
FECRT	faecal egg count reduction test

Resistance in ascarids

Only one UK investigation of resistance in *Parascaris equorum* has been published, with fenbendazole and ivermectin each being assessed on two studs (Relf et al, 2014). Administration of fenbendazole reduced *P. equorum* FEC, with FECR values in excess of 95% in both populations examined. Ivermectin was not effective in reducing *P. equorum* FEC by 95%, indicating potential resistance in both populations (FECR range: 25.5–91.2%). Clinicians working on stud farms consider *P. equorum* resistance to macrocyclic lactones (both ivermectin and moxidectin) to be common in the UK and, in some regions, ubiquitous (Cameron, unpublished data). Fenbendazole appears to remain effective, although there are anecdotal reports of resistance on UK stud farms (Tzelos et al, 2016) and it has been documented in Australia (Armstrong et al, 2014).

Table 1. Expected strongyle faecal egg count reduction and egg reappearance periods following treatment with licensed anthelmintics in anthelmintic-sensitive worm populations according to product datasheets

	Expected faecal egg count reduction	Expected egg reappearance period
Fenbendazole	>90%	6–8 weeks
Pyrantel	>90%	4–6 weeks
Ivermectin	>95%	6–8 weeks
Moxidectin	>95%	12 weeks

There are anecdotal reports of resistance to pyrantel in the UK (Cameron, unpublished data), and it has been reported in the USA (Peregrine et al, 2014) and Australia (Armstrong et al, 2014). Further investigations of AHR in ascarids in the UK are warranted.

Resistance in tapeworms

There are currently no reliable means of identifying AHR in equine tapeworm species, other than performing critical tests that necessitate euthanasia following treatment; this has not been undertaken in the UK. There is a suspicion of *Anoplocephala perfoliata* resistance in the UK (Matthews, unpublished data), but this is not proven. Tapeworm infestations have been documented that appeared to persist, based on antibody titres, despite regular treatment (Hodgkinson, unpublished data); however, in most, treatment combined with pasture management ultimately resulted in a reduction in antibody titres, suggesting a high level of re-infection from the environment as opposed to AHR.

Resistance in other helminth species

Resistance in other equine endoparasites, for example, large strongyle species, has not been reported in the UK.

Key Points

- Reduced cyathostomin egg reappearance periods (indicating early resistance) are common following treatment with pyrantel, ivermectin and moxidectin.
- Reduced cyathostomin egg count reduction (indicating more advanced resistance) following treatment with fenbendazole is now considered ubiquitous in the UK. Neither a single nor 5-day dose can be considered effective, unless efficacy is confirmed using a faecal egg count reduction test (FECRT).
- Reduced cyathostomin egg count reduction following pyrantel is increasingly common in many regions, particularly on studs, so it should not be used without assessment of efficacy with a FECRT.
- Ivermectin and moxidectin resistance is likely to be common in ascarid populations on UK stud farms.
- There is no published evidence of anthelmintic resistance in *Anoplocephala perfoliata*, but this may represent limitations of the available diagnostic tools.

Persistent *Oxyuris equi* (equine pinworm) infection is an increasing clinical problem (see below), but it is unknown whether this is related to an inherent lower efficacy of AH against this parasite, reinfestation with eggs in the horse's environment or genuine AHR.

Fasciola hepatica (liver fluke) is rare in horses, but infection may occur in horses grazing with ruminants. In sheep resistance to triclabendazole is common; it is therefore likely that this drug will also be ineffective in horses (see below).

Reducing the need for anthelmintic treatment

With appropriate management measures designed to reduce levels of helminth infection in the environment, the need for AH will be reduced, so appropriate stocking, pasture management and quarantine are critical to preserving the efficacy of AH.

Appropriate stocking

- Helminth pasture burdens are likely to increase with increasing stocking density, especially with higher numbers of youngstock (*Figure 1*). Younger animals, particularly foals and yearlings, have lower immunity to parasites and are more likely to excrete higher levels of eggs in faeces increasing the overall burden within the population (Relf et al, 2013). FEC monitoring allows identification of groups that are shedding higher numbers of eggs and therefore of paddocks that are more heavily contaminated. Stocking density in these paddocks should be reduced and efforts to reduce pasture contamination increased.

Key Points

- Aim to minimise stocking density.
- Aim to maintain consistent horse populations and use faecal egg counts (FEC) to identify problem animals and groups.

Pasture management

Effective pasture management is critical to reducing the need for AH treatments. A number of measures may be employed to reduce the numbers of infective larval stages on pasture.

- **Faecal collection:** frequent faecal collection is proven to be effective in reducing numbers of eggs shed in faeces (Tzelos et al, 2017) and numbers of infective larvae present on pasture (Herd, 1986). Current recommendations are that faeces should be removed at least twice per week (Corbett et al, 2014), especially when environmental conditions are conducive to the development of strongyle larvae from eggs and for larval translocation from dung onto pasture (i.e. moist conditions and temperatures >10°C). Further research is required to define parameters to inform frequency of faeces removal in different conditions. Harrowing of fields to spread faeces in place of faecal collection is counterproductive, since this will spread parasites across the entire area.

Figure 1. Younger animals, particularly foals and yearlings, have lower immunity to parasites and are more likely to excrete higher levels of eggs in faeces, increasing the overall burden within the population.

- **Dung heaps should be separated from grazing areas:** endoparasites can migrate many metres across pasture. Precise distances have not been determined and will vary with climatic conditions. Dung heaps should be kept at distant locations, and/or be fenced off. Tapeworm infections have been shown to spread between paddocks, presumably within the intermediate host which provides even greater mobility; as such any 'exclusion' zone may be ineffective in controlling tapeworm infection (Austin, unpublished data).
- **Pasture rotation:** it is a common misconception that equine helminths will not overwinter on pasture. Strongyle larvae can survive on pasture and tapeworm cysticercoids can survive within oribatid mites unless temperatures are extremely low for extended periods. Survival on pasture has been shown to be as long as 6–9 months (Nielsen et al, 2007) for strongyles. By contrast, in hot dry weather survival of strongyle eggs may be as little as a few weeks (Nielsen et al, 2007). It is thought that ascarid eggs may survive on pasture for years irrespective of climatic conditions. Therefore, turning horses out in spring onto pasture that was heavily contaminated in the previous grazing season places them at risk of infection. If pasture is to be rested, it is best rested in hot, dry weather. Permanent pasture on stud farms presents a particular problem as levels of contamination can increase rapidly, particularly if stocking densities are high and the same nursery paddocks are used year on year.
- **Grazing with ruminants:** ruminants will reduce numbers of strongyles, ascarids and tapeworms on pasture.
- **Other management factors:** preventing the development of rough areas of pasture where horses repeatedly defecate, as these may serve as a reservoir for parasites.

Key Points
- Collect faeces at least twice weekly.
- Rest and rotate pasture, particularly on stud farms.
- Be aware that parasites can overwinter on pasture.
- Be aware that worm larvae spread on pasture and roughs, or faeces deposited at the edge of fields, will serve as a source of infection.

Quarantine procedures
When adult horses are moved onto a property it is usually advised that they should receive moxidectin and praziquantel to eliminate as many parasites as possible prior to turnout. This is based on the assumption that they are unlikely to be carrying moxidectin or praziquantel resistant helminths, and by administering this combination, worms resistant to other anthelmintic compounds are prevented from reaching the property. Treatment would ideally follow a FEC, particularly in young stock in order to identify the relevant importance of different parasites. Following treatment, new horses should ideally be stabled for 2 weeks prior to a FECRT being performed to confirm the efficacy of moxidectin. However, as reduced FECR following moxidectin has not been reported in the UK, a more practical compromise is to keep the horse stabled for 3 days to allow excretion of any parasite eggs present in the gastrointestinal tract at the time of admission and treatment. All faeces from quarantined horses should be disposed of and should not be spread on the property.

Key Points
- On arrival moxidectin and praziquantel should be administered.
- New animals should be quarantined for a minimum of 3 days after de-worming and the faeces not spread on paddocks.
- A faecal egg count reduction test (FECRT) should be performed 10–14 days after treatment prior to turning horses out onto pasture. If there is less than a 95% reduction in FEC, then an alternative product should be used before turnout.

Assessing the need for anthelmintic treatment
There is a good level of awareness amongst the profession that interval dosing in line with the strongyle ERP is an obsolete concept. Occasional strategic preventive treatments are indicated in some circumstances, particularly in foals, but most treatments can be targeted based on evidence of risk of disease in the individual or the population and supported by diagnostic tests. Assessment of the need for AH use necessitates performing FEC to assess levels of strongyle egg shedding, and either serum or saliva antibody testing to assess tapeworm burden. Given the threat of multi-drug class AHR in the UK, it is important that efficacy of strongyle treatment is assessed on an annual basis, using a FECRT.

Faecal egg counts (FEC)
Why?
Helminth egg excretion is over-dispersed in horse populations such that a minority of animals are likely to shed higher numbers of eggs persistently. In adult horse populations exposed to low to moderate levels of pasture contamination, the 80:20 rule applies: 80% of the parasite eggs are excreted by 20% of the animals (Lester et al, 2013a, b) (*Figure 2*). By targeting AH use for higher egg-shedding individuals, the level of infective parasites on pasture is lowered (assuming good management practices) reducing treatment frequency in the population and maintaining refugia (Van Wyk, 2001) (*Figure 3*). Correlation between a single FEC and total worm burden in the individual is limited, such that a one-off FEC cannot be used reliably to indicate disease risk in an individual. However, when used regularly and on a population basis between spring and autumn, FECs are invaluable for informing the need to treat individuals to reduce egg contamination into the environment. In adult horses, FECs are focused on cyathostomin egg excretion, but are equally important in younger horses for assessing ascarid egg shedding and efficacy of anti-ascarid treatments.

The use of FEC in a targeted worming strategy has been shown to reduce the cost of de-worming when compared with intensive (moxidectin-based) interval treatment protocols (Lester et al, 2013b).

When?
The timing and frequency of FEC analysis depends on the risk to the population which is related to several factors (*Table 2*); in higher risk populations FEC should be performed more frequently. There is no merit in performing FEC within the ERP (*Table 1*) unless a FECRT (see below) is being performed or a reduced ERP is suspected on the property.

In most populations, FEC should be performed every 8–12 weeks through the grazing season (*Figure 4*). Climatic conditions will affect the development of parasites on pasture, but FEC should typically be performed from March–September. Over winter there is less egg shedding, horses generally spend more time stabled, and most will have received a larvidical anthelmintic with a long ERP, so there is less value in performing FEC during this time.

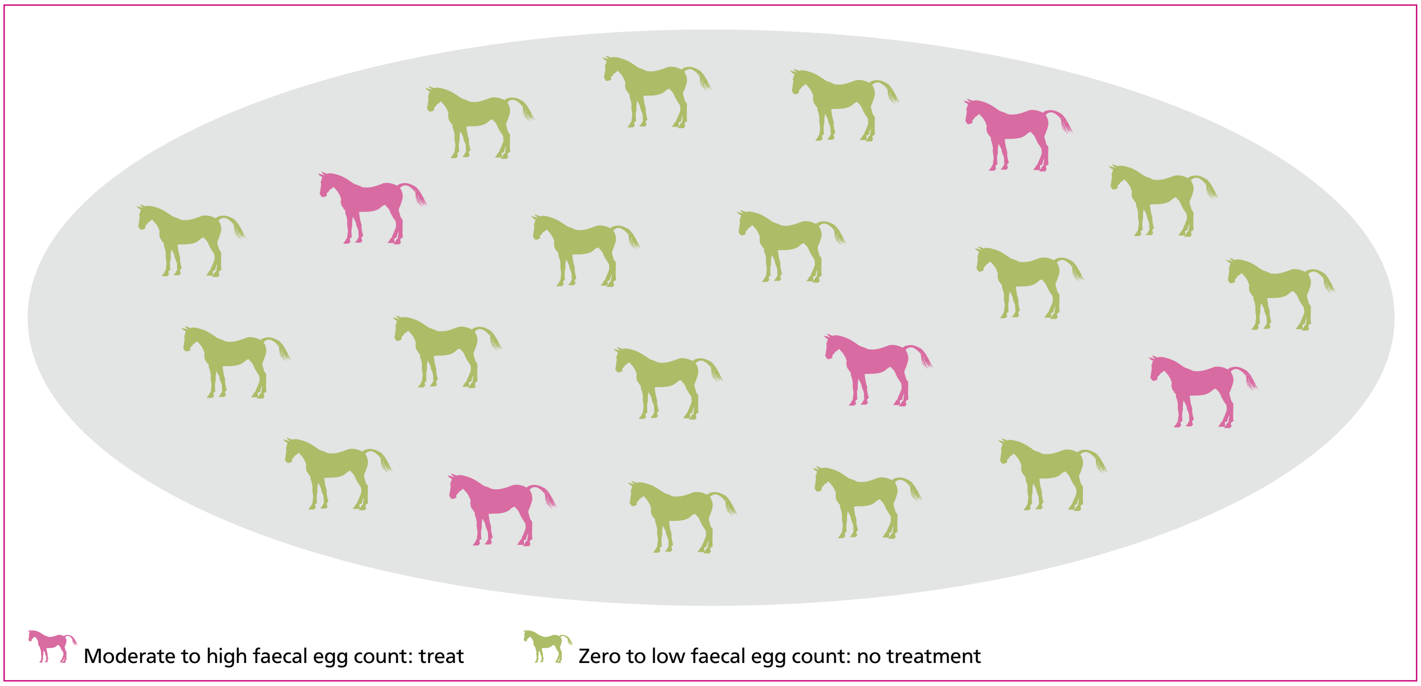

Figure 2. Cyathostomin populations are over-dispersed; this can be used to minimise drug treatments, yet reduce contamination of pasture with larvae.

The more FEC that can be performed the better, as more information is obtained on the nature of infection within any group of horses. However, in the authors' experience, compliance reduces if more than three FEC are recommended per grazing season. FEC analysis should be performed on all horses in the group, preferably at the same time. Some owners perform FEC in mid-late autumn immediately before the administering a dose of moxidectin/praziquantel for encysted strongyles and tapeworms (Rendle, unpublished data); if treatment is administered regardless of FEC results to prevent larval disease, there is less value in performing a FEC wat this time in adult horses. but it does provide further information on levels of excretion and exposure within the group. It is better to perform a final FEC in late summer and treat at this time

Key Points

- Frequency of faecal egg counts (FEC) should be determined by the risk to the population.
- In most populations of adult horses three FEC spaced equally between March and September is considered by the authors to be appropriate
- Implementation of regular FEC and targeted worming is often perceived as an added cost, but has been shown to reduce the cost of de-worming.

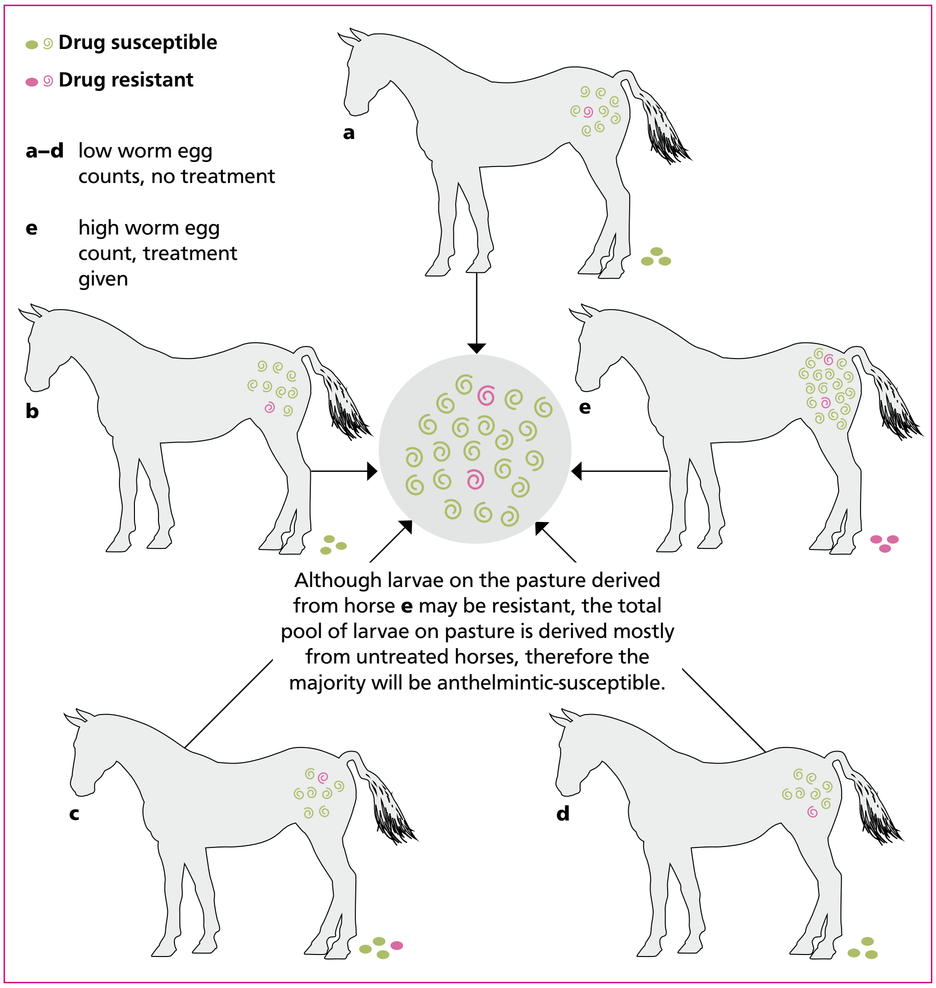

Figure 3. Refugia can be maintained if treatments are targeted appropriately.

Table 2. Risk factors for parasitic infection. Classifying horses as low, medium or high risk can help in determining the required frequency of diagnostic testing and appropriate treatment

Factors indicating a low risk	Factors indicating a moderate risk	Factors indicating a high risk
Repeated negative FEC/tapeworm antibody levels	Low/moderate FEC/antibody levels	High FEC/antibody levels
Cohorts negative FEC/tapeworm antibody levels	Cohorts low FEC/tapeworm antibody levels	Cohorts high FEC/tapeworm antibody levels
5–15 years old	>15 years old	<5 years old
Faecal collection > twice per week	Sporadic faecal collection	No faecal collection
Good pasture management	Moderate pasture management	Poor pasture management
Stable population	Occasional movement	Transient population
Low stocking density	Medium stocking density	High stocking density
No youngstock		Grazing with youngstock
Effective quarantine		No quarantine
No history of parasitic disease		History of parasitic disease
No history of colic		History of colic
		AHR identified on property by FECRT

AHR, anthelmintic resistance; FEC, faecal egg count; FECRT, faecal egg count reduction test

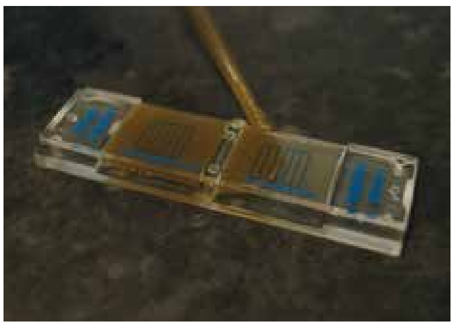

Figure 4. Performing a faecal worm egg count.

Box 1. Equation for performing a faecal egg count reduction test

$$\text{Group FECR (\%)} = \frac{\text{Pre-treatment group mean FEC} - \text{Post-treatment group mean FEC} \times 100}{\text{Pre-treatment mean FEC}}$$

if necessary. In late summer, numbers of fecund parasites, and therefore egg excretion, is likely to peak, so treatment at this time helps to reduce infective stages on pasture at a time of maximal refugia. In foals, FEC performed in the autumn are helpful in assessing the need for treatment of ascarids and/or strongyles.

How?

Detailed discussion of the merits of FEC methods is beyond the scope of this article and is published elsewhere (Lester and Matthews, 2014). For the purposes of routine monitoring, most recognised methods, ideally quantitative, are acceptable. There is no regulation or accreditation of FEC, providers and there are anecdotal reports of variation between providers so a reputable laboratory should be used. Variability in FEC test results can be reduced by following a standardised protocol:

1. Collect samples for individual horses within 12 hours of excretion
2. Take one to three samples from at least three different balls of faeces to generate a sample the size of a table tennis ball (40–50 g)
3. Place the sample in a zip-lock bag and expel the air prior to sealing
4. Keep the sample refrigerated prior to posting
5. Ensure the sample is analysed within 5 days of collection, preferably within 2 days
6. Ensure the sample is mixed thoroughly prior to processing.

Results of >200–250 eggs per gram (EPG) are considered indicative of the need to treat with AH in most populations, to reduce levels of pasture contamination. Thresholds should be set on a risk assessment basis (*Table 2*), with the threshold being higher (even as high as 500 epg) for lower risk populations, i.e. adult horses at low stocking density on clean grazing, and the threshold being lower for higher risk populations, i.e. younger horses, higher stocking density, suboptimal pasture management.

Faecal egg count reduction tests (FECRT)

Unfortunately, FECRT are rarely performed in equine practice (Easton et al, 2016). The test is simple but requires the use of a quantitative FEC method that has a low multiplication factor (Lester and Matthew, 2014). FEC are performed prior to and 10–14 days after AH treatment of those horses that have a high FEC (*Box 1*). If there is insufficient reduction in egg count (*Table 1*), then treatment failure (e.g. failed administration or under-dosing) or resistance are suspected, and should be further investigated with repeat FECRT. Resistance cannot be determined reliably unless results are available for at least six, preferably ten, horses (Vidyashankar et al, 2012).

Key Points

- Faecal egg count reduction tests should be performed annually in the grazing season.
- Some commercial FEC providers offer this service free of charge to encourage best practice.

Tapeworm antibody testing

Exposure to tapeworms can be determined using either a serum or saliva antibody test. Both have been subject to robust validation (Proudman and Trees, 1996; Lightbody et al, 2016).

Key Points

- The concept of routine 6–12 monthly treatment for tapeworms in adult horses should be discontinued.
- Antibody testing on serum or saliva should be performed 6–12 monthly (determined by level of risk) to inform on the need for treatment.
- Both serum and saliva tests have a high negative predictive value, so they are reliable in identifying horses that might be at risk of tapeworm-associated disease.
- In youngstock, strategic dosing is justified if there is known to be a high risk of disease; however, testing to determine disease risk is preferred after weaning.

False negative results are uncommon, and both tests reliably identify horses that may be at risk of tapeworm-associated disease. Initially antibody tests were recommended to be used at herd level to give an indication of the overall level of infectivity of pasture and transmission to horses. More recently the use of antibody tests to target treatment to specific individuals has been advocated (Lightbody et al, 2018). Less than 50% of adult horses in the UK are infected with adult tapeworms (Morgan et al, 2005; Pittaway et al, 2014; Lightbody et al, 2016), small numbers of tapeworms are not considered pathogenic (Fogarty et al, 1994), and clinical disease associated with tapeworms in adult horses is rare (authors' unpublished data). The traditional approach, to routinely treat for tapeworms annually or 6-monthly without diagnostic testing, is obselete. In younger horses, particularly on stud farms, tapeworm-associated disease is more common (Cameron, unpublished data), and more regular monitoring/treatment is indicated. Level of infection often appears to be associated with certain pastures, and the use of diagnostic testing helps in identifying groups of horses that are at higher risk. Antibody testing should be performed every 6 to 12 months according to risk (*Table 2*), ideally on a population basis. Prevalence of infection is generally highest in autumn, so this is the logical time to perform annual testing.

Treatment should be performed if antibody levels suggest a moderate to high burden (Kjaer et al, 2007). Both serum and saliva tests have high sensitivity for detecting these cases at the expense of specificity in order to ensure individual horses that might be at risk of disease are not missed. The positive and negative predictive values for identifying horses with >20 tapeworms are around 70% and 95%, respectively, for both serum and saliva tests. The recommended 'cut-off' for disease risk in the serological assay has recently been increased to an absorbance of ≥0.7, to reduce the number of horses that are treated unnecessarily (Kjaer et al, 2007). Tapeworm antibodies in foals can be maternally derived, so there is no merit in performing tapeworm antibody testing prior to weaning.

Sustainable treatment strategies

Sustainable control of cyathostomins during the grazing season

Fenbendazole, pyrantel, ivermectin and moxidectin are all licensed for reducing patent strongyle numbers and reducing egg excretion during the grazing season. Resistance to fenbendazole is ubiquitous, so benzimidazoles should not be used unless efficacy has been demonstrated with FECRT. **Moxidectin has the least evidence of resistance and is the most effective option in treating clinical cyathostominosis. Its efficacy needs to be preserved and its prophylactic use reduced.** Furthermore, moxidectin is lipophilic and is excreted slowly, which *may* facilitate the development of resistance in parasites that are exposed to sub-therapeutic concentrations of the compound after treatment. Currently, moxidectin dominates AH sales (UK pharmaceutical Industry sales data) and it is important for sustainable parasite control that its use becomes more strategic.

Rumours circulate among horse owners that there are safety concerns with moxidectin and ivermectin use in Shetland and Miniature Shetland ponies. The authors are unaware of any reports to substantiate these concerns and suspect that they are unfounded. Concerns possibly relate to a greater risk of overdosing in smaller equids, with resultant toxicity. Ideally, all horses would be weighed prior to deworming to ensure accurate dosing. In smaller equids it is particularly important that an accurate weight is obtained prior to the administration of anthelmintics, and particularly moxidectin given its lipophilic properties.

Ivermectin and pyrantel are currently the preferred drugs for routine treatment in response to high FEC test results. As resistance to both drugs has been reported in the UK, FECRT should be performed annually to check efficacy. Pyrantel has the potential advantages that it reduces selection pressure against macrocyclic lactones, has efficacy against ascarids and will have efficacy against *A. perfoliata* even at a routine (single) dose (Lyons et al, 1989), which may reduce the overall need for AH (see below). Ivermectin has the advantage that it will kill other parasite species, such as large strongyle larvae, as well as some cyathostomin larval stages and *Gasterophilus* spp. Although annual rotation of AH classes has not been demonstrated to reduce resistance in equids, there is some logic to alternating the use of pyrantel and ivermectin annually for use in horses with high FEC.

Traditionally, it was advised to 'dose and move' to reduce numbers of helminths transmitted to clean grazing. This serves to reduce refugia, thereby increasing selection pressure, and is contraindicated on most properties with reasonable management. On poorly managed properties where levels of infection are high, dose and move strategies may still need to be practiced to reduce the number of eggs shed onto the new pasture and thereby reduce total AH use after horses have moved.

Key Points

- Pyrantel or ivermectin are the treatments of choice through the grazing season and should be administered to horses with a faecal egg count (FEC) >200–250.
- Faecal egg count reduction tests (FECRT) should be performed annually.
- Moxidectin should be preserved for larvicidal treatments in the autumn/winter.
- Dose and move strategies should not be necessary on well managed properties.

Autumn de-worming — reducing the risk of larval cyathostominosis

De-worming at the end of the grazing season has traditionally been recommended to reduce the risk of larval cyathostominosis (*Figures 5–8*). Administration of a larvicidal AH (moxidectin) aims to eliminate the majority of larval stages, as well as adults, reducing the risk of disease and reducing the number of parasites that survive to the following season. The use of fenbendazole is no longer recommended, as resistance among cyathostomins is ubiquitous. In moderate- to high-risk animals, this strategic autumn treatment is prudent; however, in low-risk animals that have been monitored through the grazing season and are on clean pastures, the use of a strategic dose may be unnecessary. Some clinicians advocate the use of ivermectin in low-risk

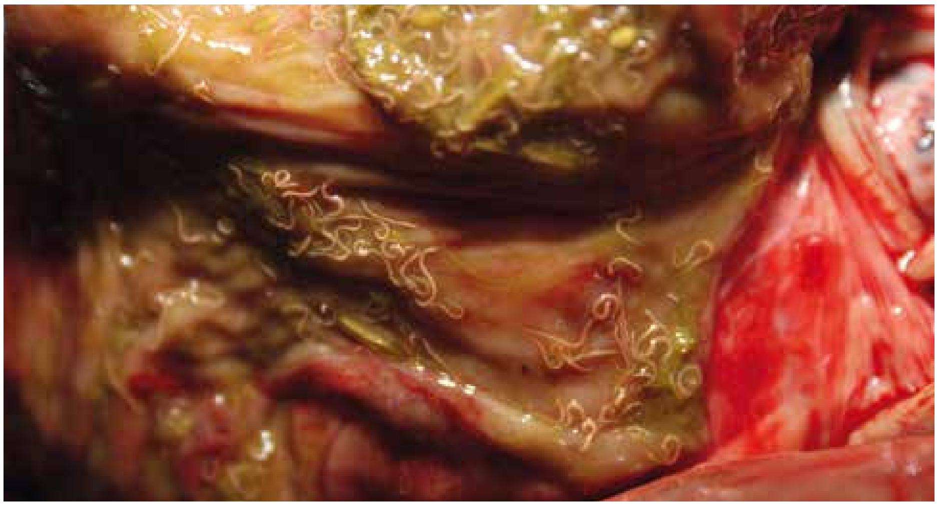

Figure 5. Cyathostomins within the large colon of a horse.

Figure 6. Cyathostomins excreted in faeces.

Figure 7. Larval cyathostomins within an oedematous colon from a horse that was euthanased after failing to respond to treatment for larval cyathostominosis.

animals in the autumn, to reduce the risk of clinical disease to an acceptable level by removing adult strongyles and some larval stages while avoiding exposure to moxidectin. Others caution against using ivermectin for this purpose, as there may be a risk of ivermectin triggering larval emergence by more selectively removing adult strongyles. If there is any doubt over management and levels of infection through the preceding grazing season, then moxidectin treatment should be administered. A serological test that informs on the presence of cyathostomins in the large intestine is being developed (Mitchell et al, 2016); when this becomes available, it will support the specific targeting of larvicidal treatments to horses that are at risk of disease, or will shed large numbers of eggs on pasture, subsequent to larval emergence.

Timing of a larvicidal AH is dependent on management and time since last treatment. Traditionally, it was administered at first frost (November), when it was considered that risk of infection from pasture reduced. This is misguided as larvae will remain infective on pasture over winter. Autumn de-worming should not be performed within the ERP of any previous treatments. Horse owners often make the mistake of treating in response to a high FEC in late summer and then administering a larvicidal dose in early autumn within the ERP of the late summer treatment. It would be more logical to postpone the larvicidal dose or to bring the larvicidal dose forward to late summer, to avoid administering two treatments when one would suffice.

Unless management is poor there should be no need for larvicidal anthelmintics to be

Key Points

- Moxidectin should be administered in the autumn in horses that are at risk of larval cyathostominosis.
- Low risk animals (*Table 2*) may not require a moxidectin treatment in autumn. Other treatments might be administered to reduce faecal egg count (FEC) in the autumn and may have some (limited) efficacy against larval stages.
- The timing of a larvicidal treatment is dependent on the quality of management on the property and the egg reappearance period (ERP) of the previous treatment.
- Reducing disease risk has to be balanced against the desire to reduce selection pressure.

administered in the spring. Youngstock grazed over the winter are more likely to require a second larvicidal treatment.

Sustainable control of tapeworms

Less than 50% of adult horses in the UK are infected with adult tapeworms (Proudman and Trees, 1996; Lightbody et al, 2016), and many of these have subclinical infections. The risk of tapeworm-associated disease in adult horses is not well quantified (Nielsen, 2015) and colic associated with tapeworm infection appears to be relatively uncommon in most populations of adult horses (Bowen, Rendle unpublished data). **Treatment should only be administered to adult horses in response to positive serum or salivary antibody testing.** Resistance has not yet been detected to either of the products licensed for the treatment of tapeworms in horses: pyrantel and praziquantel.

The use of pyrantel should be avoided where treatment is being targeted against tapeworms specifically, to reduce unnecessary exposure of strongyles to this drug. Praziquantel is preferred in such circumstances. Where the use of moxidectin is required concurrently, a combined product is available. However, when possible the use of moxidectin should be avoided and combined praziquantel and ivermectin products would be preferred. The licensed praziquantel-only product has recently been withdrawn in the UK; however, praziquantel paste is available in the UK via veterinary surgeons as a 'special' formulation.

While pyrantel is licensed for the treatment of tapeworms at 13.2 mg/kg of pyrantel base ('double dose'), a 6.6 mg/kg ('single dose') has been demonstrated in one study to reduce tapeworm numbers by 60–100% (Lyons et al, 1989). Thus, horses that have received a single dose of pyrantel will have had an anthelmintic treatment that will have had some effect on *A. perfoliatia*, and may not require further treatment. The authors would not advocate the use of a 'single dose' of pyrantel specifically for anti-tapeworm treatments.

Tapeworm eggs continue to be shed following the death of the parasite, due to degradation of segments, and remain infective in the environment. Therefore, horses suspected to have a tapeworm burden should be kept stabled following tapeworm treatment and faeces disposed of away from grazing areas. The exact duration horses should be stabled is not known, but 3 days is common practice.

Figure 8. Weight loss in a horse with chronic cyathostominosis.

Key Points

- Treatment for tapeworms should always be based on diagnostic testing results.
- Praziquantel is preferred over pyrantel for this purpose, as it is narrow-spectrum.
- Praziquantel can be obtained as a 'special' or, if a need has been demonstrated for concomitant strongyle treatment, as a combination product.
- Ivermectin combinations should be used where possible, to reduce use of moxidectin.

Youngstock

Immunity to parasites increases up to the age of 5 or 6 years and then wanes in horses in their late teens. The majority of clinical larval cyathostominosis cases are 1–3 years of age (Love et al, 1999). FEC should direct treatment of youngstock through the grazing season as they do in older horses, but special consideration should be given to youngstock when devising control programmes, to account for their lower immunity (*Figures 9* and *10*):

- The frequency of FEC should be increased given the propensity of youngstock to develop larger patent burdens more rapidly
- FECRT must be performed annually to ensure efficacy of treatments
- Clearing of faeces from paddocks at least twice weekly is essential and should be prioritised over faecal collection for older horses
- Rotational grazing is more important in youngstock than adults, as parasites will accumulate more rapidly on pasture. Grazing should be rested after it has been grazed by youngstock, preferably during hot dry weather
- All youngstock should receive moxidectin and praziquantel in the autumn and, if management is poor, they may require a second treatment 3 months later, particularly if they are grazing through the winter. The requirement for a second larvicidal treatment will further increase if the winter is mild, stocking density is high or faecal collection is inadequate
- The need for tapewrom treatment should be determined by serum or salivary antibody testing.

Foals

FEC and FECRT should be used in foals to inform decision making; however, pre-patent infection is an important cause of disease and strategic treatments also need to be administered, particularly if stocking densities are high. *P. equorum* is an important cause of disease and resistance is common. Migrating larval stages cause respiratory disease in young foals and patent infections are a common cause of (potentially fatal) colic. Clinical signs in foals are typically seen from late summer or early autumn. *Strongyloides westeri* is rarely a cause of disease, and preventive treatment targeted against this parasite is not warranted unless there is a history of disease on the property.

- Routine treatment of mares prior to foaling should not be necessary if mares are well managed.
- Foals should be turned onto clean pasture, and the use of the same nursery paddocks year-on-year is not recommended.

Figure 9. Foals require special consideration when implementing targeted worming programmes.

Figure 10. Parascaris equorum *is an important cause of disease and resistance is common.*

- All foals should be treated with fenbendazole at 3 months of age (possibly 2 months if there is a history of disease on the property) and again at 5 (or 4) months of age.
- In foals born early in the year, at 7–8 months of age FEC should determine the need for treatment against *P. equorum* (fenbendazole), cyathostomins (ivermectin) or both (pyrantel). In later foals, this will coincide with strategic autumn de-worming and there may be less benefit to performing FEC; however, the information is still useful in determining the relative importance of cyathostomin and ascarid treatment (see below).
- Moxidectin should be administered in autumn/winter, with precise timing dependent on risk and the age of the foal. Moxidectin is not licensed in foals less than 4 months of age but foals of this age would not be expected to be at risk of cyathostominosis.
- If there is a suspicion of moxidectin-resistant *P. equorum*, then a FEC should be performed to determine whether additional treatment with fenbendazole or pyrantel is necessary.
- Foals are unlikely to require treatment for tapeworms unless there is a particularly high level of exposure on the property. If treatment is considered in older foals then serum or saliva antibody testing ought to be performed to confirm that it is necessary. Younger foals (<3 months) should not need to be treated, as exposure will be negligible, and testing results are meaningless as antibodies to *A. perfoliata* are maternally derived (Austin, unpublished data). Measurement of salivary antibodies to *A. perfoliata* is unreliable in foals that are nursing due to the potential for antibodies in milk to contaminate the saliva sample. Note that praziquantel and moxidectin combinations are not licensed in foals under 6.5 months of age. Ivermectin and praziquantel combinations are licensed in foals over 2 weeks of age. No recommendation can be made for extemporaneous praziquantel, but licensed praziquantel products are safe down to 2 weeks of age.

Integrating control of other parasites

Gasterophilus spp. (bots)

Gasterophilus spp. are not considered a cause of disease and do not require treatment.

Oxyuris equi (pinworm)

O. equi is an increasingly common cause of perineal pruritus. It is not known whether this is due to resistance, climate change or reduced AH use associated with targeted worming programmes. Knowledge on efficacy of different classes of AH against *O. equi* is patchy and it is not possible to recommend a specific treatment, other than to emphasise the importance of hygiene and decontamination of the environment. The perineal region should be cleaned once, preferably twice, daily to remove eggs and break the life-cycle, and a petroleum jelly spread in this area to make it less conducive to female worm migration and to try to prevent eggs from sticking. The environment and everything in it should also be cleaned regularly.

The authors would ADVISE AGAINST:

- Inserting AH into the horse's rectum. The adult parasites are too far proximal to be affected and the AH will simply be excreted to contaminate the environment with the next passage of faeces
- Applying AH to the perineal region, as adult parasites will not be affected and eggs could simply be removed by cleaning
- Indiscriminate and/or frequent use of different classes of AH solely to try and eliminate *O. equi*. This is unlikely to resolve the clinical signs and introduces an unnecessary selection pressure for other parasites.

Strongylus vulgaris and other large strongyles

Strongylus vulgaris has increased in prevalence in association with reduced use of AH in Denmark (Nielsen et al, 2014). This 're-emergence' has not been identified as a cause of disease in the UK but remains a potential concern. Annual ivermectin or moxidectin administration is sufficient to eliminate larval stages of large strongyles. If pasture is well managed, FEC are performed and exposure to other parasites is repeatedly low then the risk of verminous arteritis is low.

Fasciola hepatica

Clinical disease as a result of liver fluke is rare in horses (Owen, 1977; Rubilar et al, 1988), even when they are grazed with ruminants that are infected. Sub-clinical liver disease is common in horses, and other causes of hepatopathy are far more likely to be responsible. Exposure to fluke can be determined using a recently developed serological assay (University of Liverpool); however, there is no means of confirming clinical infection in horses. In a recent study, four (1.8%) of 224 horses sampled at an abattoir had adult flukes in the liver and the seroprevalence of *F. hepatica* was estimated as 10.2% (95% CI 5.3–17.1%) (Hodgkinson, unpublished data). Triclabendazole is often used if fluke infection is suspected; however, in liver fluke populations infecting sheep triclabendazole resistance is widespread, and the same liver fluke populations are known to infect both sheep and horses (Daniel et al, 2012; Hodgkinson unbuplished data), so it is questionable whether the use of triclabendazole has any merit. It is unknown whether alternative flukicidal products used in sheep are safe in horses, but there are anecdotal reports of the use of closantel.

Effecting change

Barriers to changing owner behaviour

It is well accepted in human psychological and social research that human decision making and behaviour is the result of complex processes involving environmental and social pressures, habits, practical and emotional barriers, and logic. It is therefore necessary to consider in-depth the reasons why people are behaving in a certain way, in order to help them to change their behaviour. We know from surveys of horse owners that they are interested in de-worming (Stratford et al, 2014b), but these surveys also corroborate more general human behaviour studies in confirming that social norms are a more powerful influence than professional advice; horse owners are more likely to do what everyone else on the yard does than what the veterinary surgeon advises them to do (Stratford et al, 2014b; Easton et al, 2016; Rose Vineer et al, 2017). Anthelmintics are available from a variety of outlets and, contrary to guidelines, are often sold without investigation of which diagnostics have been performed and which product is most appropriate. This makes it easy for owners to obtain the products they think they should be using or cost the least money, rather than the most appropriate product. Most owners indicate that they engage with targeted worming, yet when questioned on what they actually do, the responses indicate that most are still de-worming at frequent intervals with the results of FEC failing to guide the need for treatment (Stratford et al, 2014b; Easton et al, 2016). A recent study set out to compare horse owners who reported that they used targeted worming strategies with those that did not, but it proved impossible to differentiate one group from the other by their actions (Hodgkinson et al, unpublished data).

Behaviour studies indicate that it is important to understand the motivation of a study population prior to trying to assist that population to change their behaviour. Thus far, research into horse owners has shown that most owners are aware that AHR is an issue; however, they may not consider that it applies to their horses (Rose Vineer et al, 2017). Most horse owners do not use FEC because they are concerned about AHR or even parasitic disease, but rather are driven to do so by other factors such as effects of parasites on performance or a desire to avoid the use of chemicals (Rose Vineer et al, 2017). Owners are more likely to engage with the concept of efficacy in their horse than resistance in the population, so the use of FECRT (particularly after the use of fenbendazole) is helpful in confirming lack of efficacy and highlighting that resistance can apply to them. Greater perceived knowledge is associated with increased use of FEC, so education is important in promoting responsible AH use (Rose Vineer et al, 2017). Owners who feel they understand and are in control of the programme are more likely to use FEC (Rose Vineer et al, 2017) (*Figure 11*); unfortunately, this does not necessarily mean they are using them appropriately (Stratford et al, 2014b; Easton et al, 2016), so regular professional contact is necessary. The use of weigh tapes should be encouraged, as estimation of weight, whether by owners or professionals, is unreliable for calculating AH doses.

Figure 11. Greater perceived knowledge is associated with increased use of FEC, so education is important in promoting responsible AH use.

The principles of behaviour change science suggest that education alone is not necessarily successful in instigating change, since education does not overcome the practical barriers that owners might face, such as difficulties getting the horse to accept a de-worming paste; difficulties choosing the appropriate AH; or livery yard restrictions that

Key Points

- Education is important in encouraging the implementation of targeted worming strategies.
- Even though they are aware of the issue of anthelmintic resistance (AHR), some studies have shown that horse owners do not necessarily see resistance or parasitic disease as an issue that applies to them.
- Horse owners may be more likely to respond to discussion of efficacy and effects on health and performance in their horse than to discussion of AHR or disease in the population.
- Horse owners are more likely to implement targeted worming strategies if they understand the process, and if others around them are doing it.
- Positive success stories from other horse owners and results of faecal egg count reduction tests (FECRT) on their property may help with owner engagement.
- Breaking worming down into five key stages may help owners to plan effectively and overcome potential barriers. For example: paddock maintenance, FEC, choosing an appropriate wormer, worming the horse, and efficacy testing.

lead to inappropriate pasture management. While most barriers can be overcome, assistance may be necessary in order to support owners in applying appropriate de-worming and management strategies for their horse. Therefore, it is recommended that advisers aim to discuss issues around de-worming to help and support owners to overcome such problems, rather than simply telling them which AH to use and the results of FECs and assuming that they will be able to manage appropriately.

Discussion with owners should break de-worming down into five key areas, for example: paddock maintenance; FEC; choosing an appropriate wormer; worming the horse; and efficacy testing. Breaking the process down into stages may help both the advisor and the owner to identify particular problem areas, and to plan for effective strategies to appropriately treat the horse or horses.

Behavioural science also shows that people usually respond well to success stories, and we therefore recommend that case studies are shared showing best practice and highlighting specific issues such as the importance of efficacy testing.

Barriers within veterinary practices

Informal market research of veterinary surgeons revealed a number of perceived barriers to implementing targeted de-worming programmes (Rendle, 2018), which highlighted the issues of compliance among horse owners, economic concerns when AH are so readily available from multiple outlets at low prices, and the low cost of AH compared with diagnostic testing. Means of overcoming these barriers are discussed elsewhere (Rendle, 2018).

Conclusions

A reduction in AH use is imperative to avoid the increased morbidity and mortality as a result of parasitic disease that is likely to accompany increased AHR. Resistance to multiple AH classes on the same property may now be common, particularly on premises with large numbers of youngstock. Youngstock often change yards multiple times as they mature, making it inevitable that AHR will spread. The principles of sustainable AH use are simple; the factors that prevent their implementation are complex. The success of any targeted worming hinges on changing human behaviour. EQ

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Effective use of saliva testing for tapeworm

EquiSal Tapeworm diagnosis	**Horses with low diagnosis history**	**Horses diagnosed as low**	**Horses diagnosed as low**	**Horses diagnosed as borderline or moderate/high**	**Horses diagnosed as borderline or moderate/high**
Environmental risk	Low risk closed herd, none with infection, good paddock management	Low risk closed herd, none with infection, good paddock management	High risk high herd turnover, other horses with infection, poor paddock management	Moderate risk closed herd, other horses with infection, good paddock management	High risk high herd turnover, other horses with infection, poor paddock management
Testing frequency	Once a year	Initially every 6 months	Every 6 months	Initially test every 6 months if burden levels are not reduced then move to high risk strategy	Retest 2-3 months after treatment determine if additional treatment required to reduce burden levels

*1. Lightbody, K. L. *et al.* (2016) Vet Clin Path, 45: 335-346. 2. Lightbody, K. L., *et al* (2017), Equine Vet J. 50: 213-219.

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