

# AASRP Sessions

Moderator: Joan Dean Rowe

## NCIS: Nematode criminal investigation service

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### Abstract

*Haemonchus contortus* wreaks havoc on small ruminant and camelid farms in many temperate parts of the world. Unlike many other trichostrongyle nematodes that primarily behave as thieves by robbing animals of body condition, *Haemonchus contortus* has the distinction of being a killer. This trichostrongyle becomes a “prime suspect” whenever complaints of anemia, weight loss, and death losses arise on farms. As a result, veterinarians need to know how to investigate the scene of the crime, and to help producers recognize and stop management factors that enable criminal behavior in the resident worm population. Control measures need to focus on not only sustaining animal viability, but also preserving anthelmintic efficacy.

**Keywords:** small ruminants, camelid, parasites, nematodes, *Haemonchus*

### Résumé

Le vers *Haemonchus contortus* fait des ravages dans les fermes de petits ruminants et de camélidés dans plusieurs régions tempérées du monde. Au contraire de plusieurs autres nématodes trichostrongylidés qui appauvrissent la condition corporelle des animaux, le vers *Haemonchus contortus* se distingue par son côté meurtrier. Ce trichostrongylidé devient le principal suspect lorsqu'on rapporte de l'anémie, des pertes de poids et de la mortalité dans les fermes. Par conséquent, les vétérinaires doivent savoir comment mener une enquête sur les lieux du crime et aider les éleveurs à reconnaître et éliminer les facteurs de régime qui contribuent au comportement criminel dans la population résidente de vers. Les mesures de contrôle doivent viser non seulement à maintenir la viabilité des animaux mais aussi à préserver l'efficacité des anthelminthiques.

### Introduction

All grazing sheep, goats, llamas, and alpacas are infected with some level of trichostrongyles.<sup>30</sup> However,

low burdens rarely pose a significant health risk, and are beneficial in that they stimulate a healthy immune response in the host. When there is a balance between the environment, hosts, and the parasites, morbidity is minimal. When worm numbers increase beyond a tolerable threshold, disease ensues in the host. While all trichostrongyle worms can produce pathology, *Haemonchus contortus* has gained particular notoriety for pathogenicity and prevalence, particularly in the southeastern United States.<sup>5,6,22,30</sup> It is a blood-feeding parasite that, in large numbers, can cause severe anemia, hypoproteinemia, weight loss, and death. Frequent, nonselective use of anthelmintics for worm control, and a disregard for sensible management practices, has led to a serious global problem with anthelmintic resistance.<sup>1,5,9,11,13,14,25</sup> In response to this growing crisis, researchers around the world have focused their efforts at exploring strategies that slow the evolution of anthelmintic resistance, and developing novel methods for worm control.<sup>1,5,9,13,14</sup> As a result of this work, recommendations for integrated parasite management have emerged that advocate non-pharmaceutical control methods, and selective-target use of anthelmintics. Veterinarians and extension agents are on the forefront of the effort to help producers understand and initiate the new recommendations in their herds and flock. Integrated parasite management requires more producer involvement and more thought to implement, but is a sustainable and successful strategy when executed properly.<sup>1</sup>

### Criminal Profile

Adult *H. contortus* are approximately 1 inch (2.5 cm) long, so they can be seen without magnification within the abomasum of a necropsied small ruminant or camelid. Female *H. contortus* worms are responsible for the nickname “barberpole worm”, because the intertwined blood-filled digestive tract and egg-filled uterus look like a striped barber’s pole. Adult male and female worms have 2 agendas in the abomasum: mating and eating. Most adults live only a few months in the abomasum, but some can survive for over a year.<sup>a</sup>

*Haemonchus contortus* worms pierce the host’s gastric mucosa with sharp mouthparts, causing blood loss.

Healthy female *H. contortus* can produce 5,000-10,000 eggs per day.<sup>7</sup> In addition to being highly fecund, this worm also has a rapid life cycle under optimal conditions: it takes only 3 weeks to go from being an egg to an egg layer! These factors, as well as enormous genetic diversity, favor rapid adaptability to selection pressure. Eggs passed in feces develop to infectious third stage (L3) larvae within a few days. The L3 larvae are released by water or other mechanical factors from feces, and subsequently move onto pasture grass in water films. Most L3 larvae are found in the lower 2 inches (5 cm) of the grass blades. The third stage larvae have a double-layered cuticle that protects them from the environment, but they can no longer feed. As a result, they have to be ingested by a host before they exhaust their energy and moisture reserves, or else they die. If the weather is extremely hot, they can use up metabolic reserves in as little as 30 days. Lack of moisture also decreases survival time. During periods of drought, transmission is reduced and producers are often lulled into a sense of false security. However, during temperate, moist times of the year, third-stage larvae can remain infective on pasture for 3 months or more. They do not tolerate repeated freeze-thaw cycles, so cold winter weather is usually lethal. The larvae fortunate enough to be ingested by a suitable host shed their cuticle in the abomasum, burrow into the mucosa, and molt to fourth-stage larvae (if not rejected by the host's immune response). Uninterrupted maturation to adulthood occurs unless some unfavorable environmental condition, such as cold weather, triggers arrested development (hypobiosis). Fourth-stage larvae can undergo hypobiosis for months, then resume development in late winter/early spring, in time to produce offspring that can take advantage of warm weather and an abundance of new hosts (lambs, kids, crias). Hypobiosis is mainly a factor in colder climates, and is less significant where winter weather is mild.<sup>30</sup>

### The Victims

Preferred hosts have undeveloped or improperly functioning immune systems that will allow worms to become established and persist in their digestive tract. As a result, youngsters in their first grazing season, pregnant and lactating females, animals receiving sub-optimal levels of dietary energy and protein, and hosts debilitated from other health issues are most at risk for developing heavy worm burdens. The periparturient rise in the fecal egg count recognized in small ruminants in late pregnancy and early lactation is associated with immune laxity. Appropriate intake of good-quality protein and energy during gestation reduces the immune dysfunction in the periparturient period.<sup>12,24</sup>

The clinical syndrome associated with health-threatening burdens of *H. contortus* is referred to as

“haemonchosis”. Both the packed cell volume and total protein concentration are reduced as a result of blood loss in the abomasum. Severely affected hosts show signs of weight loss, ill thrift, soft stool, and anemia. The fecal egg count can exceed 50,000 eggs per gram in heavily infected animals, although morbidity can be seen at much lower egg counts.

In livestock herds and flocks, trichostrongyles are unevenly distributed among the population.<sup>2</sup> Approximately 20-30% of the herd or flock harbour 80% of the total parasite load in the herd (“80:20 rule”). Resistance to establishment of parasitic infections is heritable, so it is advantageous to identify the heavily affected animals for treatment purposes as well as for culling purposes.<sup>1,19</sup>

### The Crime Scene

The typical crime scene contains components of the following features: a small ruminant or camelid breeding farm with a high stocking rate, use of permanent pasture (no rotational grazing), a grazing season punctuated by high rainfall and warm weather, suboptimal nutrition, and lack of appropriate biosecurity measures for new arrivals and sick animals. Frequent nonselective use of anthelmintics, combined with limited understanding of appropriate application or efficacy, further sets the stage for *H. contortus* to run rampant. Many of these recommendations, such as treating all the livestock with anthelmintics at the same time at set intervals, and then moving them to a “safe” (less parasite-contaminated) pasture did not arise from producer ignorance or neglect. Producers have been doing exactly what veterinarians and extension agents have been telling them to do since the 1960s!

### Extenuating Circumstances (multi-drug resistance)

Anthelmintic resistance in worms of livestock has become a worldwide phenomenon, and it is rapidly progressing in both severity and prevalence.<sup>11</sup> Producers became “drug-dependent” when there was an abundance of effective, safe, and inexpensive anthelmintics on the market.<sup>1,26</sup> Sensible management that limited worm transmission took on a lesser role, and there was no reason to evaluate animals individually for their fitness to withstand worm challenge. This approach to worm management was effective for awhile, but it proved to be unsustainable.<sup>25,26,28</sup> Whole-herd treatment has the unintended consequence of selecting for anthelmintic resistance, because worms that survive exposure to the anthelmintic become the main genetic contributors to subsequent worm generations. The less dilution from anthelmintic-susceptible worms (refugia), the faster anthelmintic-resistant genes accumulate in the next

worm generation. Refugia consists of worms in hosts not exposed to anthelmintics, and eggs and larva on pasture.<sup>25</sup> At this point in time, resistance to anthelmintics is evolving more quickly than pharmaceutical companies can replace the ones that are failing. It is unlikely that this trend is going to change in the foreseeable future.

Before 2000, there were not many reports on anthelmintic resistance in the United States, but reports are now commonplace.<sup>9</sup> In addition, the magnitude of the anthelmintic resistance is steadily increasing. By 2006, a study conducted on 46 sheep and goat farms in the southeastern United States demonstrated that *H. contortus* isolates were resistant to benzimidazoles, levamisole, and ivermectin on 98%, 54% and 24% of the farms, respectively.<sup>8</sup> Resistance to all 3 major anthelmintic classes was evident on 22 farms (48%), and total anthelmintic resistance (ie, resistance to benzimidazoles, levamisole, ivermectin and moxidectin) was identified on 8 farms (17%). Moxidectin resistance is continuing to worsen, according to more recent studies.<sup>9</sup> Although the situation does not appear to be as dire in camelids, the same trends are evident.<sup>22</sup> Larval developmental assays conducted on 32 camelid farms showed that 28 farms (97%) had multi-anthelmintic resistant *H. contortus* isolates.<sup>22</sup> Resistance to the benzimidazoles, ivermectin, levamisole and moxidectin was noted in 100%, 88%, 22%, and 22% of farms, respectively. Total anthelmintic resistance was documented on 1 farm.<sup>22</sup>

It is unlikely that new anthelmintics are going to provide more than a temporary respite from treatment failure if the ways producers use anthelmintics in general fail to change. Monepantel (a new aminoacetonitril derivative) was released by Novartis under the name Zolvix® in New Zealand in 2009, and subsequently in other countries. A recent report indicated that resistance to monepantel developed in a goat herd after only 2 years of use.<sup>21</sup>

### **Limit Misconduct by Worms: Integrated Parasite Management**

Integrated parasite management programs utilize pasture management strategies that reduce worm transmission, make animals more fit to withstand parasitic challenge through good nutrition and genetic selection, and reduce selection pressure for anthelmintic resistance through sensible and selective use of anthelmintics. Although these recommendations sound daunting, it is important to stress to producers that little changes result in big results over time.

#### **Pasture Management**

1. Reduce stocking density to reasonable levels (5-7 per acre).<sup>5</sup> It can become virtually impossible to

manage nematodes in small ruminants and camelids on overgrazed, crowded permanent pasture because the level of exposure can become overwhelming.

2. Be aware that areas of hypertransmission (“hot spots”) can develop where animals congregate (such as night-time holding pens and milking pens), and in areas that stay wet.<sup>1</sup> Holding pens should be totally devoid of grass. Some producers have successfully managed these “hot spots” by applying gravel to keep the area drier. Grass regrowth is managed with herbicides or by blow torches. Hay can be fed from feeders off the ground in lieu of grazing. Wet, boggy areas can be fenced to keep animals out of them, and wet areas around water tanks kept dry.

3. Pasture rotation. In temperate times of the year, pastures can be rested for 3-6 months to allow infective larvae to die off to “safer” levels.<sup>5,30</sup> Alternate grazing with horses or adult cattle help clean up *H. contortus* larvae (not pathogenic in these species). This strategy has the added benefit of improving pasture utilization. Fast rotational strategies (move animals to a “safe” pasture plot every 4 days) are of great benefit.<sup>17</sup> It is a more labor-intensive strategy that requires use of multiple small paddocks for implementation.

4. Use of browse rather than graze allows animals to eat higher off the ground, thereby avoiding infective larvae.

5. Forage high in condensed tannins appropriate for the geographic area can be planted to improve nutrition and provide anthelmintic benefit.<sup>17</sup> Go to wormx.org to access resources on use of condensed tannins.

### **Nutrition**

The link between nutrition and parasite resistance in small ruminants has been well established in the past decade, mainly to meet the need to develop sustainable approaches to nematode parasite control.<sup>23</sup> In particular, ingestion of high-quality metabolizable protein is vital for the maintenance of immune function and parasite resistance/resilience.<sup>12,24</sup> Herd (flock) problems with severe parasitism often coincide with inadequate nutrition. Both issues need to be addressed to achieve a good outcome. Submit forage and supplemental feed samples to a reputable testing laboratory such as Dairy One, Inc. Consultation with a veterinary nutritionist will help producers establish an optimal nutrition program, that will in turn improve resilience to parasitic challenge.

### **Genetic Selection for Resistance and Resilience**

Factors such as resistance and resilience in small ruminants are under genetic influence.<sup>19</sup> Resistance is defined as the ability to resist establishment of a parasitic infection. The fecal egg count is a practical marker of this trait. Resilience is defined as the ability



to withstand infection with a minimal degree of morbidity. The hematocrit and FAMACHA score are practical indicators of resilience. Heritability estimates for fecal egg count and FAMACHA score range from 0.19 to 0.25 (on a scale of 0 to 1.0) in sheep under moderate to high environmental challenge from *H. contortus*.<sup>19</sup> This level of heredity is significant enough to expect meaningful improvement within 5 years of selective breeding for these traits.<sup>1</sup> Changes in body weight in the face of parasitic challenge also provide good information about an animal's resilience.<sup>1,4</sup> Some producers achieve genetic improvement simply by culling the lightest animals (10-20%) to slaughter each year; only the heavier, well conditioned animals (in an age-matched group) and breeding females are retained. Since breeding males contribute up to 50% of the genetics of future offspring, it is particularly important to select them for desirable traits such as resistance and resilience to parasite challenge.

### Animal Monitoring for Worm Infection

The majority of the animals in most herds and flocks have low parasite burdens, and they will not gain much benefit from anthelmintic treatment. As a result, it makes sense to treat part of the herd or flock (targeted selective treatment) and leave the animals with minimal-to-no morbidity untreated to provide refugia. Useful mottos such as "leave the best, and treat the rest", and "look before you treat", have been promoted to help farmers grasp the essential concepts.<sup>1,26</sup> Monitoring animals for parasitic burdens can be accomplished by monitoring fecal egg counts, and various physical parameters. Fecal egg count tests, and ways to monitor herds for anthelmintic resistance are discussed in the "Fecal Fluency" presentation.

From a practical standpoint, the main obstacles to use of selective targeted treatment strategies is that it takes more time and cognitive effort by producers to implement them. However, regular observation of physical parameters such as changes in body weight, body condition score, fecal consistency, condition of the wool or hair coat, and pallor of the conjunctiva are useful indicators of overall health, so the benefit of these observations extends beyond worm control. It is important to recognize that worm infections are the greatest health threat in most herds and flocks under moderate to high parasitic challenge, so these parameters are practical indicators of which animals (20:80 rule) are harbouring the largest parasite burdens, and are most in need of treatment.

Animals in optimal-to-high body condition are less likely to be harbouring health-threatening worm burdens than are animals with suboptimal body condition scores. With practice, producers can quickly achieve proficiency at assigning body condition scores. It is im-

portant that these determinations are made by palpating the back (particularly the loin area between the dorsal and transverse processes) and sternum, rather than by visual assessment alone. Fleece or wool can conceal the actual body condition. Routine evaluation of body weight every 2 weeks is another useful way to detect animals that are failing to gain weight as well as their growing contemporaries, or that are failing to maintain their body weight.<sup>1</sup> Small ruminants and camelids often develop loss of fecal consistency in association with high worm burdens, so unformed feces is another clue to infection intensity. These indicators are applicable to many trichostrongyle pathogens (including *Teladorsagia circumcincta*, *Trichostrongylus colubriformis*, *Nematodirus* spp., and *H. contortus*), as well as coccidian pathogens.

The pallor of the ocular membranes is a useful physical parameter for assessment of intensity infection with *H. contortus*, since it is a hematophagous worm that causes clinical anemia.<sup>1</sup> The FAMACHA<sup>®</sup> System was developed to enable producers to compare the color of their animals' lower conjunctiva with color blocks on a standardized laminated card, so that treatment decisions could be made on the spot. Francois Malan, a South African veterinarian, is credited with observing the association between hematocrit and eyelid pallor in parasitized sheep in South Africa.<sup>18</sup> He and his colleagues developed the FAMACHA<sup>®</sup> chart, which depicts 5 illustrations of ocular membrane colors: 1: deep red (nonanemic), 2: red-pink (nonanemic), 3: pink (mild anemia), 4: white-pink (anemic), and 5: white (severely anemic). The acronym, "FAMACHA" is derived from Dr. Malan's nickname (Faffa), his last name (Malan), and the word "chart". The FAMACHA system was later validated for use in South African goats.<sup>27</sup> Studies conducted in the United States on sheep and goat herds with a high prevalence of *H. contortus* demonstrated that the FAMACHA<sup>®</sup> eye score, packed cell volume, and fecal egg counts were all highly correlated.<sup>3,10</sup> Use of the FAMACHA<sup>®</sup> System was also validated for use in camelids.<sup>29</sup> Since introduction of the FAMACHA System to the United States in 2004, over 29,000 FAMACHA<sup>®</sup> cards have been distributed, and numerous workshops have been conducted to teach small ruminant producers how to implement the concepts in their herds and flocks.<sup>20</sup> Results from recent surveys demonstrated that producers see obvious benefit from use of the FAMACHA<sup>®</sup> System.<sup>20</sup> Inquiries about FAMACHA<sup>®</sup> cards can be directed to famacha@uga.edu. Veterinarians and owners can purchase the cards, but producers need to have proof of having received training in FAMACHA<sup>®</sup> technique.

### Recommendations for FAMACHA<sup>®</sup> Use

1. Score animals in natural light, and use the FAMACHA<sup>®</sup> card for comparison. Score both eyes, and

if a discrepancy is noted, assign the palest score to the animal to err on the side of safety.

2. Score animals every 2 to 3 weeks during the expected *Haemonchus contortus* season (in areas with a seasonal incidence). Otherwise, evaluate them all year.

3. Always treat the animals scoring in FAMACHA® categories 4/5 and 5/5. Animals scoring in categories 1/5 and 2/5 that also are in overall excellent body condition do not require treatment.

4. Many animals in FAMACHA® category 3/5 are not truly anemic, but it is best to treat them if any doubt exists as to their status. Treat animals scoring in FAMACHA® category 3/5 if they have any of the following risk factors: (1) youth (weanlings and yearlings), (2) in the periparturient period (3) underweight or showing other signs of morbidity associated with parasitism, and (4) if over 10% of the animals in the herd or flock are scoring in the 2 palest categories.

### Farm Biosecurity

Many producers take a casual approach to introduction of new animals onto their pastures in that few impose an appropriate quarantine period. This practice allows anthelmintic-resistant parasites (and other diseases) to move easily from 1 farm to another. The consequences are often not immediately apparent, but can become problematic later, as infective agents and parasites spread and amplify.

New animals need to be housed off pastures in an area where feces can be easily removed and disposed of away from areas where the herd or flock grazes. The new animal is treated with a triple combination of anthelmintics (from the 3 different classes currently on the market), sequentially on the same day. A fecal egg count is performed 10 to 14 days later. If combination treatment results in a negligible reduction in the fecal egg count, then the animal should not be allowed access to communal grazing areas. If treatment effectively reduces the fecal egg count (>95%), then the new animal can be grazed on pastures contaminated with resident trichostrongyle larvae to help dilute out any remaining anthelmintic-resistant trichostrongyles.<sup>1</sup>

### Sensible Use Of Anthelmintics

This topic is covered in more detail in “Extending the Efficacy of Drenches” <http://www.sheepandgoat.com/ACSRPC/Conference/conference.html>. Nine main points are listed below:

1. Know what worms are in the herd or flock. Test anthelmintic sensitivity every 2-3 years.

2. Weigh animals and use a treatment chart to ensure proper dosing. Recently updated dosing charts for sheep and goats are available at [www.wormx.org](http://www.wormx.org).

3. Use oral anthelmintics (NOT topical or injectable products) for worm control, and use medications formulated for oral use.<sup>14,15,16</sup>

4. Dose deep into the oral cavity using a calibrated dispenser with a nozzle that can reach to the back of the throat. Administer the dose slowly and steadily.

5. Goats require 2X the sheep dose for most anthelmintics. Levamisole is the exception to this rule: use a 1.5-times increase over the sheep dose in goats.

6. Withhold feed for 12 to 24 hours prior to treatment with benzimidazoles.<sup>5</sup>

7. Use a combination of anthelmintics from several different classes when low-level resistance is present. This practice does not accelerate anthelmintic resistance. In fact, use of high-efficacy combination anthelmintic treatments delays the progression of anthelmintic resistance. The more effective the treatment, the greater the dilutional effect the refugia will have on the anthelmintic-resistant worms that survived treatment.<sup>14</sup> The dose of each medication used in the combination drench should not be decreased. The medications should be administered sequentially, and should not be pre-mixed in the same syringe. Meat and milk withdrawals are assigned based on the medication used with the longest withdrawal time.

8. DO NOT use long-acting preparations for worm control. These products have been shown to reduce refugia and accelerate the rate of anthelmintic resistance.<sup>14</sup>

9. DO NOT treat all (or even most) of the animals and then move them to a new pasture. Field trials have demonstrated that this practice assures that the pasture will be re-populated mainly with anthelmintic-resistant worms, particularly when little residual refugia in the form of eggs or larvae are on the pasture.<sup>14</sup>

### Conclusion

The era of fixed-interval, whole-herd, and repeat-treatment anthelmintic protocols is past, as these practices rapidly induce anthelmintic resistance. Sustainable management of trichostrongyle nematodes, particularly *H. contortus*, requires a multi-faceted approach that emphasizes use of non-pharmaceutical strategies, and targeted selective treatment. The concept of retaining animals for breeding that demonstrate superior resistance and resilience in the face of parasite challenge has great merit. As the supply of effective anthelmintics continues to dwindle, non-pharmaceutical control measures will become increasingly important to the small ruminant industry around the world.

### Endnotes

<sup>a</sup>Bob Storey, personal communication

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