PEER REVIEWED

Considerations for control of helminths in stocker cattle

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Abstract

Many factors influence the spectrum and magnitude of helminth populations in stocker cattle. Calves are placed into stocker operations during all seasons, from all regions of the country, and with a broad range of prior parasite exposure and parasiticide treatment. This makes it unlikely that a generalized or generic parasite control program will be effective for all animals at receiving. Follow-up treatment recommendations are equally problematic, contingent upon the success of the treatment protocol utilized when cattle arrived at the stocker operation, residual activity of the anthelmintic(s) used at arrival, parasite challenge during the stocker phase, general animal health, and producer expectations.

At the farm or ranch level, the more troublesome and conflicted considerations regarding parasite control are often ignored, and treatments are based on what appears to have worked in the past or the current cost of treatment options. This paper is not intended to make detailed recommendations about worm control, but is instead a discussion of factors at play in stocker cattle, including the species of the parasites, biology of the parasites, parasiticides, and the interaction and effect of these factors on the health and productivity of stocker cattle.

Key words: bovine, stocker cattle, helminths, anthelmintics

Résumé

Plusieurs facteurs influencent le type et la magnitude des populations d'helminthes chez les bovins d'engraissement. Les veaux sont placés dans des parcs d'élevage en toute saison et proviennent de plusieurs régions du pays. Leur exposition passée aux parasites et aux traitements antiparasitaires peux donc varier beaucoup. Il est donc peu probable qu'un programme généralisé ou générique de contrôle des parasites puisse être effectif. Les recommandations pour les tests de rappel sont également problématiques et peuvent varier en fonction du succès du protocole de traitement utilisé à l'arrivée des bovins au parc d'élevage, de l'activité résiduelle de l'anthelminthique utilisé à l'arrivée, de la charge parasitaire pendant la période au pâturage, de la santé général de l'animal et des attentes de l'éleveur.

Au niveau de la ferme ou de l'exploitation bovine, les aspects les plus controversés du contrôle des parasites sont souvent ignorés et les traitements sont basés sur les méthodes qui semblaient fonctionner par le passé ou sur le coût actuel des options de traitement. L'intention de cet article n'est pas de faire des recommandations détaillées sur le contrôle des vers mais plutôt d'offrir une discussion des facteurs importants chez les bovins d'engraissement, incluant l'espèce de parasite, la biologie de ces parasites, les antiparasitaires et l'interaction et l'effet de ces facteurs sur la santé et la productivité des bovins d'engraissement.

Introduction

Helminth burdens can impact health, welfare, and productivity of stocker cattle. Several factors influence the spectrum and severity of helminth populations in stockers, including the age of the animals, severity of exposure, and prior parasiticide treatment. Cattle in stocker operations are usually recently weaned, and originate from all regions of the country; previous management is rarely known.

Stocker cattle are typically treated on the farm or ranch for internal parasites when in-processed at arrival. Treatment can improve immune system function in parasitized calves, and deworming can be expected to improve forage intake and feed utilization and subsequently increase weight gain. Veterinarians and producers must also develop protocols to manage new parasite infections acquired after turn-out onto pasture at the stocker operation. All of these issues make the understanding of the biology of helminths, diagnostics, and efficacy of anthelmintics extremely important for optimal control.

This article is intended to provide a review of the more important helminth parasites in stocker cattle (Table 1), but does not include those of lesser importance, including *Trichuris* spp (whipworm), *Dictyocaulus viviparus* (lungworm), *Bunostomum phlebotomum* (hookworm), and *Moniezia benedeni* (tapeworm). Detailed information on helminth parasites of cattle in the United States is found in several parasitology text

Table 1. Helminth parasites most frequently found in significant populations in stocker cattle.

	Helminth-specific attributes
Nematodes	
Abomasum	
Ostertagia ostertagi (brown stomach worm)	Seasonal and intraburden arrestment Benzimidazole tolerance, and macrocyclic lactone resistance (?) Overcomes effective immune expulsion
Haemonchus placei (barber pole worm)	Most prevalent in the south Highly fecund with compensatory fecundity Long patency period
Trichostrongylus axei (small stomach worm)	High incidence, but most frequently small population size Usually not of concern
Small intestine	
Cooperia punctata and *C. oncophora* (the "cooperiads")	Macrocyclic lactone resistance Not necessarily "mild" pathogens Extremely high (~100%) incidence Effectively immunogenic
Nematodirus helvetianus (thread-necked worm)	Macrocyclic lactone resistance Low, but increasing (?) incidence Effectively immunogenic Environmentally resistant
Strongyloides papillosus (thread worm)	Relatively high incidence Only mildly pathogenic Usually not of concern
Large intestine	
Oesophagostomum radiatum (nodular worm)	Percutaneous and oral routes of infection Relatively low incidence Usually not of concern
Trematodes	
Liver	
Fasciola hepatica and *Fasciolodes magna* (liver flukes)	Geographically and topographically restricted Anthelmintic tolerance and resistance

books.[a,b,c] A discussion on the epidemiology and control of nematode parasites of cattle is presented elsewhere,[40] and is not re-visited in detail here. In addition, this paper discusses anthelmintics currently in use in the US, along with different management strategies for effective helminth control.

Helminths in Stocker Cattle

Historically, *Ostertagia ostertagi* was considered the most important nematode in stocker cattle. Based on nematode counts taken during necropsies of cattle in Arkansas over the last several years, *O. ostertagi* burdens appear to be declining, and hence this parasite may no longer be the most significant nematode in beef cattle. Several factors may have contributed to the possible decrease in *O. ostertagi* prevalence. Extensive use of macrocyclic lactones (MLs) since 1982 might well explain this observation. Macrocyclic lactones were and are highly efficacious against this nematode, with only 1 published report of ML resistance by *Ostertagia* in the US.[9] Correspondingly, the benzimidazoles have been used less frequently during this time period, a class of compound that is generally less efficacious against *Ostertagia* than the MLs.[39] Coupled with its susceptibility to the most popular anthelmintics, *Ostertagia* is short-lived as an adult, and not a very fecund nematode compared to others, and therefore resistant adults have not been able to noticeably expand their populations over the last 3 decades. Nonetheless, *O. ostertagi* is still an extremely common and pathogenic nematode in the US, with necropsy-based incidence approaching 100% across all cattle age groups and production types. This nematode should be considered in any treatment regimen, especially because of its innate tendency to arrest in the abomasum of cattle at the early fourth larval stage (IEL_4) in the winter (northern US) or in the summer (southern US).[35] These arrested populations are not removed by levamisole, and removed at varying rates by benzimidazoles.[39,43] Therefore, MLs, either alone or in combination with a benzimidazole, should be considered for receiving treatment of stockers from areas of the country where inhibition is likely.

Based on necropsy worm counts in Arkansas, *Haemonchus placei* is more prevalent today than in years past. This nematode is innately capable of withstanding pasture stage desiccation that accompanies drought. Additionally, this nematode can persist in northern stocker operations where presumably new infections are brought in annually by stocker calves from the south where the worm flourishes. In addition to tolerance of adverse ambient conditions, *Haemonchus* is also a very fecund nematode with relatively low numbers of adults producing high fecal egg counts. *Haemonchus* burdens in stocker-type cattle have been demonstrated to exhibit resistance to the MLs in Wisconsin[11] and Texas.[d] *Haemonchus contortus,* the sheep counterpart to *H. placei* of cattle, is probably the most important nematode parasite of sheep in the United States, and is the parasite most responsible for parasite-induced pathology and drug resistance that extends across all classes of anthelmintics.[14]

Trichostrongylus axei is the third helminth of importance, and the last abomasal worm of consequence in US cattle. This nematode parasite is fairly common, but almost always in low numbers and eclipsed by populations of other strongyles. *T. axei* is the only routinely encountered nematode parasite that cattle "share" with horses.

Cooperia spp (cooperiads), with both *Cooperia oncophora* and *C. punctata* well represented in the US, are common small intestinal parasites of stocker cattle. These nematodes may now be the most important parasite in stocker cattle, as they are found in robust numbers in cattle ≤ 2 years of age, capable of considerable pathology,[1,30] responsible for most of the current concern over ML resistance,[19] and suggested to be of increasing pathogenicity that is tied to the relative degree of resistance.[26] For many years, treatment of cattle ≤ 2 years of age with a ML has resulted in the cattle passing feces containing only *Cooperia* spp eggs for weeks post-treatment. This "cleansing effect" has resulted in the post-treatment propagation and recycling of monoculture ML-resistant *Cooperia* spp populations on stocker operations where MLs are the primary, if not sole, class of compound in use.

Two nematode exceptions to the above "post-treatment monoculture" scenario are *Nematodirus helvetianus* (discussed later) and *H. placei*. Over the past few years in Arkansas, coprocultures of feces from calves recently treated with MLs have yielded infective larvae of *Haemonchus* in addition to the overabundance of *Cooperia* spp L3. Despite this relatively recent finding of continued fecundities by *H. placei* after ML treatment, the cooperiads continue to be the nematodes that command the most attention in stocker operations. Persistence of the cooperiads in the face of ML treatment is not limited to the US, as they plague stocker-type cattle worldwide as well.[19] In the United Kingdom, a blanket suggestion has been made to treat all incoming young cattle with a benzimidazole followed with levamisole a few days later, hold the cattle in dry-lot for 2 days post-treatment, and then place the cattle on pasture, all in an attempt to curb populations of ML-resistant *Cooperia* spp.[4] The cooperiads are fortunately limited to younger animals (≤ 2 years of age),[13] an epidemiologic factor that greatly, albeit not entirely, limits the concern over ML resistance to younger cattle.

Nematodirus helvetianus, or thread-necked worm, is a very capable pathogen tolerant of adverse ambient conditions. Larval stages are retained in the protective egg in the feces for extensive periods of time, and the parasitic stages are innately more tolerant of MLs than are the cooperiads.[3,42] *Nematodirus* infections are generally restricted to younger cattle (≤ 1 year of age), with nematodiriasis primarily viewed as a calf hood disease. Despite its restriction to younger cattle, *N. helvetianus* appears to be expanding its prevalence. The change in levels of infection are due assuredly to the lack of effective control afforded by the MLs and perhaps compounded by global warming, with the worm being afforded the time and ambient conditions to go from 1 to 2 generations of infection per grazing season.[21]

The last nematodes discussed here are *Strongyloides papillosus* and *Oesophagostomum radiatum*. Both are relatively common, especially where pasture moisture abounds, as both nematodes are capable of both percutaneous and oral infection. Neither nematode, however, has been singled out as important in the US. *S. papillosus* infections cause transient enteritis in the small intestine.[32] The diagnostic problem presented by *S. papillosus* in cattle (and sheep) is that the eggs can be misidentified as strongyle eggs by inexperienced technicians, which can cloud results from fecal egg count reduction tests (FECRT). Pathology caused by *O. radiatum* is primarily the result of nodule formation in the terminal small intestine in response to the development of histotropic fourth-stage larvae.[25]

The final helminths commonly diagnosed in stocker cattle are liver flukes, *Fasciola hepatica* and *Fascioloides magna*. *F. hepatica* is the most prevalent liver fluke, with pockets of *F. magna* (deer fluke) generally in the same geographic region as *F. hepatica*, but also observed to be in discrete areas where *F. hepatica* is not commonplace.[e] These 2 trematodes are restricted to geographical areas optimal for snails that serve as the intermediate host. Liver fluke infections are common in the northwestern, southeastern, north-central, and south-central US. Epidemiologic patterns for flukes vary by region of the country,[6,24] and in accordance with farm-specific grazing patterns, as those factors which govern persistence and abundance of infective metacercariae ultimately determine the incidence and magnitude of bovine fascioliasis.[7]

Efficacious flukicidal treatment of calves in the northwest[16] and southeast[23] resulted in improved animal performance over untreated cattle, demonstrating the significance of liver fluke infections in certain regions of the US. Stocker calves originating from or grazing in fluke-endemic areas should be considered for flukicidal treatment. No medications are currently available for effective elimination of immature flukes, leaving adulticidal therapy the only option. Treatment will partially reduce the fluke burden of treated calves, but perhaps more importantly lessens or prevents contamination of otherwise suitable pasture with *F. hepatica* and *F. magna* eggs and environmental stages.

Anthelmintics for use in Stocker Operations

A listing of anthelmintics (Table 2) is simple, but documentation of their efficacies is much more elusive, involved, and constantly in need of reassessment. There are 2 popular *in vivo* methods of evaluating anthelmintic efficacy, the FECRT and the control study. The FECRT is the most commonly employed tool to assess anthelmintic efficacy as no animal sacrifice is required, and the study can be attempted at any cattle operation given the observance of a few required procedures (Table 3). Regrettably, the FECRT can lead more to speculation of anthelmintic efficacy than to documentation. The control study, on the other hand, is a definitive demonstration of efficacy of an anthelmintic. Study animals are either treated or left untreated, sacrificed post-treatment, and respective worm burdens quantified and compared. Aside from doing the study correctly, the challenges with

Table 2. Anthelmintics available for use in cattle.

Class of compound	Molecule(s)	Comments
Imidazothiazole	levamisole	• limited spectrum of activity • requires oral administration • does help address ML resistance • possible problem of availability
Benzimidazole	fenbendazole oxfendazole albendazole	• all as oral formulations, but fenbendazole has several feed grade forms • do help address ML resistance • albendazole indicated for adult flukes • not indicated for inhibited *Ostertagia* infections
Avermectin (macrocyclic lactone)	ivermectin doramectin eprinomectin	• pioneer and generic preparations of ivermectin • appears that generic preparations are not as efficacious as the pioneer • topical and injectable formulations • ML resistant strains of *Cooperia*, *Haemonchus* and perhaps *Ostertagia* • eprinomectin is also available as an extended release injectable
Milbemycin (macrocyclic lactone)	moxidectin	• topical and injectable formulations • ML resistant strains of *Cooperia*, *Haemonchus* and perhaps *Ostertagia*
Sulfonamide	clorsulon	• combined with "plus" preparations of MLs for adult flukicide activity

Table 3. "Rules" for a well-constructed, fecal egg count reduction test (FECRT).

- Minimum of 10 animals per treatment group, with all animals from a homogeneous pool (treatment history, grazing history, etc.)
- A control (untreated) group in addition to the treated group(s)
- Evenly disperse infections (do pre-treatment fecal egg counts for even allocation to treatment group, and remove all animals with a negative egg count)
- Coproculture eggs for genera specifics as fecal egg count reductions are a function of the drug and the genus of worm
- Give the correct treatments (weigh each animal, measure the doses accordingly, and administer with no loss of product)
- Observe proper time frames between day 0 egg counts and post-treatment egg counts:
    - about 7 days for imidazothiazoles (levamisole)
    - about 14 days for benzimidazoles (fenbendazole, oxfendazole and albendazole)
    - about 21 days for macrocyclic lactones (ivermectin, doramectin, eprinomectin, moxidectin)
    - If animals are in dry-lot or on clean concrete (free from post-treatment challenge), then wait until day 28 for the post-treatment fecal egg counts and coprocultures, thereby giving some time for the partially affected nematodes to resume egg production
- Sample the same, uniquely-identified animals at pre- and post-treatment
- Do all egg counts with a well-practiced, referenced quantification procedure, and use 100% feces each time (not mucus, blood, etc.)

the control study are: 1) to have a homogeneous set of cattle in the study whose infections reflect the parasite burdens of their counterparts in the industry, and then 2) to interpret the results and calculated drug efficacy within that context.

Several control trials have been conducted at the University of Arkansas within the last 6 years using calves obtained from local cow-calf operations. Presumably, these calves were infected primarily with nematodes acquired at the cow-calf operation as they had not yet been extensively treated and co-grazed with other similarly managed animals. As a result, these calves had not yet been subjected to conditions that would foster intense propagation and accumulation of resistant forms (i.e. stocker-type conditions). These animals were considered typical of cattle received by stocker operations. In the most extensive study done at the University of Arkansas in the recent past,[39] injectable moxidectin and ivermectin formulations were compared to drench formulations of fenbendazole and oxfendazole. All were pioneer products and administered according to label directions. The anthelmintic efficacies demonstrated in this study are summarized in Table 4. Only moxidectin effectively removed (> 90% removal) all nematode populations that were present at adequate incidence for product evaluation. Neither fenbendazole nor oxfendazole were efficacious against *Ostertagia* populations, and ivermectin was not efficacious against either *Cooperia oncophora* or *C. punctata*. In addition, ivermectin was less than efficacious against developing fourth stage populations of *O. ostertagi*, an observation that hinted at a possible tendency toward development of ML resistance by *Ostertagia* which has subsequently been documented elsewhere in the US.[9]

In a more recent control study, calves acquired from cow-calf operations and entering the stocker phase of production were treated with either a generic topical formulation of ivermectin, topical moxidectin, or injectable moxidectin (Table 5).[36] Only the *Cooperia* spp infections in "new" stocker calves were shown to have acquired some degree of resistance against the MLs in the 3 years since the previous control study.[39] For all products, >90% efficacy was demonstrated against adult *O. ostertagi*, *T. axei*, *H. placei*, and *O. radiatum*. Moxidectin pour-on was also >90% efficacious against all remaining adult nematode populations found in these cattle (*C. punctata*, *C. oncophora*, and *N. helvetianus*). Injectable moxidectin activity against *C. oncophora* was not efficacious in this later study, and topical generic ivermectin was not efficacious against *C. punctata*.

Two points of contention regarding nematode control in cattle were addressed in the above study: 1) "Are topical MLs as efficacious as injectable MLs containing the same molecule?", and 2) "Are generic MLs as efficacious as the corresponding pioneer products?" These data,[36] as well as data from Arkansas and elsewhere, show equivalent efficacies for the 2 routes of administration of MLs. Topical application of MLs with coincident allo- and self-grooming allows for efficacious levels of anthelmintic to be delivered to the gastrointestinal nematode through the combination of percutaneous and oral routes. Topical application of MLs without grooming results in lower drug bioavailability than oral or injectable administration as measured in blood.[22] It should be emphasized, however, that topically applied MLs are subject to wide "swings" in "drug-to-parasite" availability due to rain, hair coat, animal finish, correctness of application, extent of grooming, and so forth; hence,

Table 4. Efficacy of anthelmintics demonstrated in a 2008 controlled trial using recently weaned, stocker cattle in Arkansas.

Nematode	Anthelmintic			
	Moxidectin 0.2 mg/kg	**Ivermectin 0.2 mg/kg**	**Oxfendazole 4.5 mg/kg**	**Fenbendazole 5.0 mg/kg**
O. ostertagi				
- adult	99.9	98.3	89.9	72.5
- IEL_4*	99.6	91.1	70.2	0.0
- DL_4**	97.6	81.9	48.1	21.9
H. placei				
- adult	100.0	97.8	97.8	100.0
T. axei				
- adult	100.0	99.8	99.5	100.0
Cooperia				
- adult *oncophora*	96.3	77.4	99.1	99.8
- adult *punctata*	98.1	84.8	97.9	99.0

*IEL_4 is for inhibited, early fourth stage larvae
**DL_4 is for developing fourth stage larvae

Table 5. Efficacy of anthelmintics in a 2011 controlled trial using recently weaned, stocker cattle in Arkansas.

Adult nematode	Drug		
	Generic ivermectin pour-on 0.5 mg/kg BW	**Moxidectin pour-on 0.5 mg/kg BW**	**Moxidectin injectable 0.2 mg/kg BW**
O. ostertagi	99.4	99.9	99.9
T. axei	97.8	100.0	100.0
H. placei	96.4	99.5	100.0
O. radiatum	100.0	100.0	100.0
C. punctata	73.4	99.9	93.6
C. oncophora	93.0	99.3	46.1
N. helvetianus	56.7	93.3	82.2

topical application is the most problematic method of administration currently available. In addition, it is noteworthy that topically applied eprinomectin, at the time of its introduction to the market in the US, conferred excellent efficacy without the need for coincident grooming.[41]

The study cited earlier[36] suggests that generic and pioneer formulations of MLs are similar in efficacy. However, this interpretation may be applicable only in respect to treatment of calves as they leave a cow-calf operation. Numerous studies have been conducted on the effectiveness of various generic ivermectin preparations over the years, and it appears that the efficacy for generics, as well as any frequently used anthelmintic, decreases significantly when animals are placed in the stocker phase of production and repeatedly treated and pastured with other similarly managed animals.

In a 2011 FECRT study,[38] stocker calves were acquired approximately 3 months after treatment with doramectin at a stocker operation, transported to a University of Arkansas research facility, and treated with either injectable or topical generic ivermectin, injectable or topical pioneer ivermectin, or injectable or topical moxidectin. Additional treatment groups included fenbendazole and combinations of fenbendazole and each ML formulation. Unfortunately, only a portion of the study comparing topically applied anthelmintics has been published;[38] a summary of the mean of individual animal egg count reduction percentages for both the topical and injectable products used in the study is presented on a treatment-group basis in Figure 1. Results from the control group, fenbendazole group, and fenbendazole/ ML group were combined from the injectable comparison and pour-on comparison segments of the study in making this figure, as these data were roughly equivalent in both segments. From this figure, it is evident that the efficacy of MLs, as reflected by FECR percentages, was depressed during the stocker phase of production. Only treatment with topical moxidectin, fenbendazole, or combination fenbendazole/ML resulted in FECR percentages > 90%, the minimum level of reduction that suggests efficacious nematocidal activity.[33] These results are similar to data from multiple sites where ML resistance, especially ivermectin resistance, is the current norm in stocker calves.[19,20] Reliance on benzimidazoles for control of nematodes in stocker cattle is not the only conclusion that should be drawn from these data, however, as combinations and rotated/staggered treatments might well provide the most sustainable and effective intervention strategies. Unfortunately, long-term (≥ 3 years at the same location) evaluations of such practices as conducted in the US have not been published.

The study summarized in Figure 1 was a fecal egg count reduction study which provided indirect evidence suggesting ML resistance in stocker cattle. In a later controlled study, a generic formulation of injectable ivermectin was evaluated for efficacy in feeder cattle as they entered the feedlot.[37] In this study, anthelmintic treatment was not efficacious for removal of *C. oncophora, C. punctata, H. placei* or *O. ostertagi* infections. However,

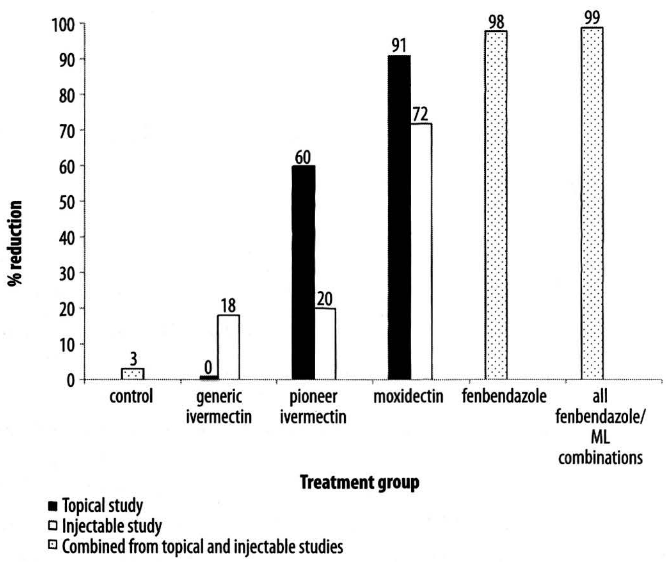

Figure 1. Mean individual animal fecal egg count reduction percentages by treatment grouping for stocker cattle treated at receiving with doramectin, and subsequently placed in a topical or injectable treatment study.

the lack of efficacy for parasite control seen in this study cannot be solely ascribed to generic ivermectin as no other anthelmintics were evaluated.

Injectable, extended-release eprinomectin was recently approved in the US for use in cattle on pasture. Several long-acting formulations of anthelmintics were once commercially available in the US, including a morantel tartrate sustained-release bolus and a sustained-release ivermectin bolus. These products provided excellent nematode control and improved animal performance, but could not be considered a commercial success. Their removal from the market was not the result of poor efficacy, but rather product-specific combinations of: 1) the lack of consumer acceptance (difficult bolus administration), 2) expense of the products, 3) the lack of strategic incorporation of the devices into management directed toward sustainable nematode control, and 4) product production problems. Injectable, extended-release eprinomectin should be readily acceptable at the working chute as it is delivered as a subcutaneous injection administered in front of the shoulder at the rate of 1.0 ml/110 lb (1 mg/kg) of body weight.

The concern with long term, continual release of eprinomectin or any other long-term anthelmintic relates to basic parasitology. Chemical intervention directed against any pathogen potentially selects for resistance. Long-term chemical intervention selects for resistance over time, plus it minimizes refugia, the population of the targeted pathogen not exposed to selective pressure by chemical intervention. With the eprinomectin extended-release product, the treated animal will have efficacious levels of the ML for approximately 100-150 days, depending on the targeted nematode/ arthropod, and then a "tail" of approximately 30 days of subtherapeutic ML levels. As a result, the potential for selection pressure towards resistance is of concern. This selection pressure is further compounded by the current resistance to some MLs by both *Cooperia* and *Haemonchus* spp parasites in stocker cattle.

A series of papers have been published on the effectiveness of long-acting injectable eprinomectin for cattle.[27] Data were collected in Arkansas, Idaho, Missouri, Minnesota, Wisconsin, Oregon, and Louisiana that clearly documented excellent nematocidal activity when using this product. Unfortunately, these data were collected approximately a decade ago, and ML resistance has expanded since this product was first evaluated. Despite reservations concerning the use of this product, its use in a well-managed and monitored manner should lead to effective nematode control and impressive improvements in animal performance. A useful suggestion for sustainable and effective use of the long-acting injectable formulation was offered in a paper by Forbes:[10] "If resistance is already present in a parasite population, then treatment with an anthelmintic with a different mode of action at the start or finish of the period of activity of a long-acting formulation may be indicated to prevent the establishment or persistence of adult worms." Since ML resistance in stocker operations is common, the quotation above translates into a recommendation for treatment with levamisole or a benzimidazole at the time the long-acting product is administered, and then again at approximately 120 days post-injection. The appropriate time point for the "piggy-back" treatment is difficult to pinpoint as many dynamics are in play, such as level of resistance on the farm, dimensions and fecundities of the worm burdens at 100 to 120 days post-injection, and the significance of "tail selection" out to 180 days post-injection. Long-acting eprinomectin should prove to be a good nematocidal therapy; the actual efficacy and sustainability of the product will be determined by the oversight put in place to guard against propagation and expansion of resistant populations of nematodes. Unfortunately, the method most suitable to evaluate the persistence of worm burdens post-treatment with long-range eprinomectin is the FECRT, a test compromised in this scenario as resistant cooperiads have been shown to maintain infections post-treatment, but suspend egg production for extended periods of time after ML treatment.[5,8] Treatment might appear to be successful based on FECRT results, but may not be efficacious in ridding the animal of the worm burden.

Considerations of Which Anthelmintics to Use and When to Use Them

The first consideration regarding anthelmintic treatment when cattle are received in a stocker operation is the history of the animals. If cattle are coming from sections of the country endemic for flukes, a flukicide should be considered. It must be understood however, that at best only adult flukes will be removed, leaving the more pathogenic, immature flukes in place. Next, if the cattle have arrested burdens of *Ostertagia* (pre-type II *Ostertagiasis*), a macrocyclic lactone should be used as only this class of anthelmintic is effective against arrested *Ostertagia* when the product is administered at the standard dose rate. Benzimidazoles have some activity against arrested *Ostertagia* at the label dose,[39] but efficacy is much improved when the label dose is doubled, as has been demonstrated for fenbendazole.[34]

The last and perhaps most overriding consideration concerning treatment of newly arrived stocker cattle is that of resistant helminths. Every anthelmintic used in cattle today in the US has been used for over 20 years, and while nematocides with novel structures and modes of action are being developed and approved for use in small ruminants in other countries,[17] their availability for use in US beef cattle is likely years away. As a result, resistant populations are the norm, not only for the macrocyclic lactones, but for benzimidazoles and imidazothiazoles as well. The extent of resistance in cattle nematodes will not be discussed here, but has been well reviewed.[20,31] This topic is further discussed in another paper in this issue of the journal.[18] Given the extent of ML resistance in the US, many veterinarians and producers now use combination treatments wherein arriving animals are treated with both a ML and a benzimidazole, either concurrently or staggered (e.g., one on the day of receipt and the other on the day of re-evaluation).[f]

Under ideal conditions, the following is a listing of desirable elements for proper use of anthelmintics in a stocker operation:

- Use a dewormer for internal parasites, and a different product for external parasites. This lessens the amount of misuse (under-dosing) for nematodes when ectoparasites are being targeted with MLs, something that often occurs with inexpensive generic preparations of topical ivermectin.
- If a combination of 2 anthelmintics is being used, it is vital that the 2 products be of different modes of action, and that each product is given at the full, labeled dose.
- Whenever an anthelmintic is administered, it should be given at a dose rate equal to or greater than the labeled dose for optimal efficacy, as contrasted to an ineffective dose that propagates resistance. This suggests weighing every animal and measuring every dose to achieve proper dosing. Alternatively, weigh the heaviest animal in a homogeneous set and use that calculated dose for each of the other cattle in the group.
- Proper dosing is particularly important when using topicals or pour-on products. There is significant animal-to-animal variation in the amount of drug that actually gets to the site of action in the GI tract with every formulation, but especially with topical products.[12,15,28,29] Variability is exaggerated with the topical or pour-on formulations due to weather (rain, sunlight), hair coat, fat cover, and grooming (self- or allo-grooming). Given that this inherent variability is mostly out of the producer's control, application of the product, which is under the producer's or veterinarian's control, should be done correctly. Pour-on products should be administered to every animal in a pastured group (grooming should result in mutual exchanges as opposed to dilutions) with care that there is no product run-off.
- Refugia should be preserved. Refugia is the population of pathogens (in this case nematodes) in a population of cattle that is not exposed to

selection pressure by anthelmintics. The use of anthelmintics, past, present, and future, is coincident with selection for resistant strains. Treatment removes susceptible populations and leaves resistant ones. The more often animals are treated, the more often susceptible nematodes are removed and the resistant ones maintained. Dilution of resistant forms, and their genes, is a function of refugia. After animal treatment, it is highly desirable for the remaining resistant worm population in the animal(s) to be quickly infused with newly acquired, non-selected worms from the pasture. Practices related to this recommendation might include not treating resident cattle (as opposed to newly acquired cattle) during extensive dry periods when pasture infectivity is low or completely restricted; not using the same class of compound on a group of commingled cattle at intervals ≤ 2 months; leaving a portion of cattle untreated, thereby providing non-selected populations of nematodes to infect the cattle that have resistant populations of parasites (this practice cannot be successfully implemented with topical anthelmintics due to allo-grooming); not dosing and moving cattle, as this practice can over-contaminate the receiving pasture with resistance-prone helminth progeny; and alternating classes of compounds, although recommendations concerning the specifics of alternating anthelmintics (within year, between years) have not been either specified or verified as effective in the long term.

- Evaluate the effectiveness of the anthelmintic. Unfortunately, the only way to test an anthelmintic on a practical basis at the farm or ranch level is the FECRT (Table 3). An anthelmintic treatment is considered effective when the fecal egg count is reduced by 90% or more.[30] If the treatment in use is providing less than 90% reduction in fecal egg count, then a lack of product efficacy is fairly certain, as FECRT percentages are usually higher than the actual worm reduction percentages.[2]

Conclusions

The stocker cattle phase of beef production is probably the most complicated for helminth control. Management and husbandry required during this phase of production both enhances the actual magnitude and importance of worm burdens, and diminishes the current and long-term efficacy of anthelmintic regimens as well. This paper provides perspectives into factors involved in stocker cattle helminthiasis, and which practices might be employed so that effective and sustainable anthelmintic intervention might be developed. Beef production per acre and per animal have never been as great as they are today. These levels of performance cannot be sustained without ongoing re-evaluation and improvement in parasite control programs.

Currently, worm control in US stocker cattle is primarily based on chemical intervention. Biological controls, such as selective breeding for host resistance, alternative pasture usage (crops, green chop, etc.), alternating host grazing (long-term grazing of sheep or horses on cattle pastures), and reduced stocking rates, are useful to some degree, but do not provide the convenient and immediate remedy that anthelmintic treatment does. Unfortunately, chemicals now in use have been on the market for many years, and their efficacies have diminished due to selection of resistance by the targeted parasitic helminths. At present, optimal helminth control is based on determining effectiveness of current measures, improving that effectiveness, and taking measures that will help sustain effectiveness of anthelmintics currently on the market.

Endnotes

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