The Economics of Parasite Control for Beef Cattle

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Introduction

Market conditions in 1996 reduced profit margins in the beef industry to subsistence levels and brought severe economic hardship to cattle producers in North America. In response to these economic challenges, many progressive cattlemen re-examined every aspect of their management, omitting procedures of dubious benefit and critically assessing the profitability of any programs that were retained.[1] Market conditions have since improved, but critical assessment of management is not a passing fad. Progressive producers will continue to make management decisions based on profitability.

All management operations should be subjected to cost-benefit analysis, especially the traditional procedures that are performed routinely. Parasite control is a relevant example because it is widely practiced and its utility and economic feasibility are taken for granted. Despite widespread adoption, however, the necessity and profitability of parasite control is controversial for some classes of cattle, particularly mature cows.[2,3]

By contrast, the cost-benefit of controlling parasites in stockers and replacement heifers is overwhelming. Yet even in these production systems, optimal profits cannot be realized until deworming is scheduled to exploit the biological characteristics of target parasites.

This paper will examine the economic feasibility of controlling gastrointestinal nematodes of cattle in North America, but the coverage will not be limited to monetary inputs and outcomes. A preliminary section will review the biology of target parasites and host responses, register concerns about the economic viability of current recommendations, and discuss realistic expectations for deworming programs. A discussion of the parasitologic characteristics of individual classes of beef cattle will follow, recommendations for optimal parasite control of each class will be offered, and the requirements for cost-benefit estimated.

Parasite Biology: The Ground Rules for Logical Control

Seasonal transmission

Unlike many other infectious organisms, nematode parasites must spend an obligatory phase in the environment before they can infect a new host. This environmental period begins when eggs are passed in the feces and ends when infective third stage larvae (L3) are ingested during grazing. All events between these two points are controlled by climatic conditions.

Eggs of gastrointestinal nematodes of ruminants hatch at temperatures ranging from 45° to 85°F; hatching occurs more rapidly at higher temperatures. First- and second-stage larvae feed on organic material in the fecal pat, and ultimately molt to the infective, third stage at a rate that is directly proportional to environmental temperature. Development of L3s is completed in as little as five days at 75 to 80F, but may take several weeks at lower temperatures.[4]

Climatic conditions favoring prolonged survival of the L3 stage are completely different, however. Infective larvae persist longer at lower temperatures and are relatively unaffected by freezing, but survive only briefly in temperatures exceeding 85F.

As a consequence of these environmental events, internal parasitism of cattle follows predictable, seasonal patterns of transmission. Spring and autumn conditions throughout North America are ideal for hatching of eggs and development of larvae to the infective stage. Thus the risk of infection (*i.e.*, number of L3 on pasture) is high during both seasons.

In the northern U.S. and Canada, little hatching or development occur during winter. Survival of L3 stages in cold weather is excellent, however, and L3 numbers do not decrease until warmer weather arrives in the subsequent spring. There is no such thing as a "killing frost" for cattle nematode larvae. By contrast, conditions during southern winters are mild enough to support hatching of worm eggs and development of new larvae.

Northern summers are ideal for development and persistence of infective stages on pasture. In comparison, southern summers are often too hot to support survival of L3 stages, and the risk of reinfection is relatively low during this season.[5] In all regions, dry weather decreases transmission because L3s require substantial precipitation to migrate from fecal pats to forage.

The sum effect of these transmission patterns is that the risk of infection from pasture in northern regions is high during most months of the year, and drops off temporarily only during late spring and early summer. By contrast, the infection index in southern regions is high from autumn through spring, but low during the summer months.

Thorough understanding of these predictable, seasonal patterns is crucial in the design and implementation of strategic parasite control programs for beef cattle in a given locale.[4]

Accumulation of parasites within the host

Most gastrointestinal nematodes do not survive long as adults in the host animal; 35 to 50 days is a typical lifespan. In addition, the most common worm species average only two or three generations per year. **Considered together, these factors refute the notion that several generations of mature parasites can accumulate and coexist within the host.**

Large numbers of gastrointestinal parasites can accumulate within the host through a mechanism known as arrested development. Arrested nematodes cease growing at an early larval stage within the host and do not resume maturation to adulthood until several months later.[6] Resumption of maturation is synchronous, and severe clinical disease (*i.e.*, type 2 ostertagosis) can result when worm numbers are large, or when the host is compromised.

Arrested development comprises a strategy for nematodes to avoid environmental conditions that are unfavorable for the development and/or persistence of their offspring. In the northern U.S. and Canada, the major inducing factor is exposure of L3s to cold temperatures in the environment. Thus, L3s ingested during autumn grazing undergo arrest within host tissues and do not resume maturation until temperatures rise in the spring. If not for arrested development, those same worms would mature to the adult stage during winter, and any eggs produced during their brief life span would fail to hatch under prevalent winter conditions.

In the southern U.S., precise conditions stimulating arrest have not been described, but summer heat is detrimental to the survival of L3s on pasture. Thus, larvae ingested during spring grazing arrest within the host and don't mature until late summer or autumn. If those worms had deposited eggs on pasture during southern summers, their progeny would survive only briefly under the existing climatic conditions.

Only certain bovine dewormers are effective against arrested larvae, so knowledge of the local, seasonal patterns of arrested development is critical for selecting appropriate anthelmintics (Table 1).

Table 1. Anthelmintics labeled for activity against arrested early-fourth stage *Ostertagia ostertagi* larvae in cattle.

Drug Class	Anthelmintic	Dosage
Avermectin	Doramectin (Dectomax; Pfizer Animal Health)	0.2 mg/kg
Avermectin	Ivermectin (Ivomec; MSD Agvet) (Ivomec Pour-On; MSD Agvet) (Ivomec SR Bolus; MSD Agvet)	0.2 mg/kg 0.5 mg/kg ~12 mg/head/day
Avermectin	Moxidectin (*Canada only*) (Cydectin; Fort Dodge Animal Health) (Cydectin Pour-On; Fort Dodge)	0.2 mg/kg 0.5 mg/kg
Benzimidazole	Albendazole (Valbazen; Pfizer Animal Health)	10 mg/kg
Benzimidazole	Fenbendazole (Safeguard; Hoechst Roussell Vet)	10 mg/kg
Benzimidazole	Oxfendazole (Synanthic; Fort Dodge Animal Health)	4.5 mg/kg

Effects of host immunity

Grazing cattle ultimately develop acquired resistance to gastrointestinal nematodes during their second year on pasture, at approximately 15 to 18 months of age.[7] Unlike other infectious organisms, immunity to nematode parasitism is usually not manifested as complete protection from infection, but rather as reduction in worm numbers and decreased susceptibility to associated disease. Accordingly, mature beef cows can be considered immune although technically they remain parasitized. Cows host far fewer worms than susceptible, juvenile cattle; two European studies reported that 80% of cull beef cows had fewer than 2500 worms.[8,9] Another consequence of acquired immunity is that beef cows exhibit low fecal egg counts, usually averaging fewer than 5 eggs per gram.[3]

Inherent Limtations of Parasite Control Recommendations

Recommendations must be customized

Even though a control program has been successful and profitable at several venues, it is unrealistic to expect similar results on every farm where it is implemented. Parasitism involves extremely complex interactions among the host, its parasites, and the environment they share.[4] Each of these elements is influenced by an unlimited array of management variables, of which anthelmintic treatment is but a single component.[10] The complexity of this system does not permit confident prediction of production outcomes from the adoption of "proven" deworming recipes.

Decisions to modify deworming practices would be simpler if the economic threshold of common parasitisms were known. An economic threshold is defined as the "population density of parasites at which the value of the damage caused is equal to the cost of control".[11] Economic thresholds, like parasitism, involve very complex interactions and extrapolation beyond the farm or herd level can be unreliable.

Parasite control cannot compensate for deficient management

Parasite control is not the most critical element in maintaining a successful beef herd. Nearly all beef consultants would consider nutrition to be the first priority for individual animal and herd performance. A second element that is more crucial than parasite control is restricted, seasonal breeding[12] because other management programs are impossible to implement when the calf crop varies widely in age.

Modern anthelmintics are extremely valuable tools, but they cannot perform optimally in undernourished cattle or in herds with a perennial calving season. Beef cattle can only be as productive as the most limiting factor in the basic management equation. Management deficiencies of this magnitude cannot be offset by anything that comes in a bottle.

Critical assessment of information sources

In evaluating parasite control recommendations, producers and practitioners should consider the sources of that information. Commercial promotion is a cherished right of capitalism, but all advertising is inherently biased. It is reassuring that the FDA rigorously polices pharmaceutical advertisements to prevent gross misrepresentation of fact. Nevertheless, it would be an incompetent "spin doctor" who couldn't operate within these limitations to cast their client's product or program in a superior light. *Caveat emptor.*

Likewise, information published in professional journals should not be exempted from similar scrutiny. The standard for reliability of scientific information is statistical significance, which indicates that the likelihood of the observed results happening purely by chance is some minimal probability (usually 5%, *i.e.*, $P<0.05$). Demonstration of a significant difference does not "prove" a biological association, nor does it constitute a guarantee of cause-and-effect. On the other hand, differences that are not statistically significant may nevertheless be real, or they could be due to chance. Non-significant differences require additional experimentation to support or refute the initial findings. By the strictest interpretation for scientific reliability, if a treatment effect isn't significantly different, then it isn't different.

In a previous article,[3] the author reviewed over 30 published trials of anthelmintic use in beef cows. The major conclusions of that review are summarized below to sensitize the reader to the potential for conflicting evidence within the scientific literature.

Deworming beef cows was purported to increase body weight, but cows gained weight in 5/12 studies reviewed, lost weight in 5/12, and exhibited no change in the other two. Treating beef cows with anthelmintics was also reported to increase conception rates. Indeed, positive responses were observed in 25/33 trials, but this advantage was statistically significant ($P<0.05$) in only 1/25.[3]

Such examples demonstrate the consequence of a pervasive flaw of experimental design in these studies: too few cows enrolled in a trial to lend statistical validity to the findings. In other words, the experimental designs were inadequate to demonstrate the effects of anthelmintic treatment over and above all the other variables affecting performance. Many of the trials reviewed had been conducted prior to the late 1980's, when the standard of experimental design began to improve markedly. Nevertheless, many of the older trials are still referenced as dogma regarding production responses to parasite control. To make informed management decisions, the beef industry deserves current data generated by studies conducted under the highest standards of experimental design.

Recomendations For Specific Classes of Beef Cattle

Nematode infections of cattle follow stereotypic patterns that are determined by host age and immune status, climate, and management.[4] The following discussions will summarize the major parasitologic characteristics of various classes of beef cattle, evaluate the evidence for economic feasibility of control efforts, identify opportunities for control in major geographic regions, and estimate the likelihood of favorable economic outcomes from deworming.

Beef Cows

As discussed previously in this paper, beef cows can be considered functionally immune to gastrointestinal nematodes because most harbor small worm burdens and exhibit low fecal egg counts.

Purported Benefits of Deworming Cows

Reports of increased cow weight and improved con-

ception rates associated with anthelmintic treatment were described in a previous section.

Increased weaning weight of calves is one of the most consistent benefits attributed to deworming beef cows. In the previously cited review,[3] untreated calves suckling dewormed cows had greater weaning weights in 7/7 trials, and treatment of both cow and suckling calf resulted in weaning weight advantages in 19/20 trials. Approximately 1/3 of those advantages were significant. It has been suggested that average daily gain might be superior to weaning weight as a measure of calf productivity because many untreated animals exhibit compensatory gains in the latter stages of a trial.[13]

Enhanced weaning weight is generally attributed to increased milk production by dewormed cows, yet the effect of anthelmintic treatment on milk yield of beef cows has been measured in only one trial. Production advantages were noted by the weigh-suckle-weigh technique on three sampling dates, but cumulative benefits were not calculated or reported.[14] Considering the paucity of lactation data from beef cows, it may be instructive to review the conclusions of similar studies with dairy cows.

Numerous reports of the effects of deworming on milk production in dairy cows have been published, but this body of literature also contains pervasive deficiencies in experimental design.[15] Only a few of the published dairy deworming trials had sufficient sample sizes to permit valid statistical analysis; the three largest studies were conducted in foreign countries.[16]

These trials were in general agreement that anthelmintic treatment soon after parturition increased milk yield in dairy cows. Highest-producing cows consistently demonstrated the greatest responses to treatment. In two studies that conducted financial analyses, milk production advantages were quantitatively modest and returned little more than the cost of drugs and labor. Treatment advantages were not significant on a herd basis, so the recommendation to deworm all cows on a farm is unfounded. Lastly, milk yield responses were not correlated to body condition, so the common practice of selectively treating only "wormy-looking" cows apparently is without basis.

Comments on Current Practices

Inappropriate timing

Traditional times to deworm beef cows are either autumn, spring , or after parturition (winter/spring). Although traditional scheduling may integrate smoothly with other management practices, these times are inefficient for optimal parasite control. The seasonal patterns of transmission in all regions of North America suggest that the numbers of infective L3s (*i.e.*, risk of reinfection) are relatively high on pastures during autumn, through winter, and into spring.

In addition, the benefits attributed to removing worms at these times are manifested at later dates in the form of improved conception rates and increased weaning weights. The apparent delay or persistence of these advantages is puzzling because cows should have been reinfected within days to weeks after the cited treatment times, and rapidly resumed their prior worm numbers. It defies conventional views of parasitic disease that a temporary respite from low levels of infection could result in substantial improvements in performance which persist for several months. If the reported benefits of deworming beef cows are indeed real, then the production-limiting effects of parasitism in immune, mature cattle are caused by mechanisms that have not been adequately characterized.[3]

Preventive maintenance

Many practitioners promote autumn deworming as a measure to prevent a clinical syndrome of severe weight loss, weakness, and eventual prostration of cows during winter. This syndrome has been attributed to parasitism because some cases respond to deworming and dietary improvement. Regardless of the clinical response, there is little evidence that parasitism causes inanition in mature cows. This syndrome requires further study to determine whether it is due to primary malnutrition, or to synergy between parasitism and malnutrition. Although deworming may be empirical for under-nourished cows, it should be recognized that rote, autumn treatment several months previously is unlikely to prevent or diminish health crises associated with malnutrition.

There is little doubt that underfed cows are exposed to more parasites as a consequence of altered grazing behavior. Hungry cattle graze more closely to fecal pats and crop forage closer to the ground.[17] Both behaviors expose cattle to more infective larvae, which are concentrated centrifugally around fecal pats and are more numerous at the base of forage grasses. Increased exposure to infective larvae might incur production penalties whether or not adult worms become established.[18] Immune-mediated rejection of incoming infections requires the use of precious protein for immunoglobulins and immune effector cells, possibly at the expense of production parameters.

Recommendations for Control

Based on existing evidence, the author does not consider deworming cows to be necessary or consistently profitable. Nevertheless, producers who continue to deworm cows may be able to extend the duration of protection from reinfection by altering the timing of treatment. Considering that most reports of production advantages resulted when deworming was performed at biologically inefficient times, even greater economic benefits may result if treatment were scheduled strategically.

Strategic deworming is based on knowledge of local parasite transmission patterns, farm management, and characteristics of the anthelmintic used. The main objective is to afford the greatest possible interval before infection is reestablished. Strategic treatment is best accomplished by deworming animals when the risk of reinfection is minimal. Precise timing varies with geography and management practices.

Southern U.S.

In the southern U.S., numbers of infective larvae on pasture are lowest during summer[5] because high temperatures cause larval mortality. Reservoirs of infective larvae persist in dried fecal pats and in soil during summer, however, and larval populations can be released by heavy rainfall.[19] Deworming in mid-summer with a product that is effective against arrested *Ostertagia* larvae[20] minimizes and postpones reinfection, and thus could be classified as strategic.

Northern U.S. and Canada

Infective larvae on pasture readily survive freezing, so parasite transmission is virtually perennial. It is common practice in northern regions to remove cows from pasture during winter,[21] however, and confinement conditions preclude reinfection.[22] Deworming cows at the onset of winter housing strategically protects them from reinfection through the confinement period.

Infective larvae surviving through winter may be present when cows are turned out in spring. Although larval numbers decline progressively as spring temperatures become warmer, delaying turnout to avoid reinfection is impractical for most northern beef operations.

Economic Feasibility

Beef cows comprise the largest potential market for bovine anthelmintics in North America, and deworming this class of cattle is promoted vigorously by the pharmaceutical industry.

Anthelmintic treatment of individual beef cows is a fairly expensive proposition. Using local drug costs (Knoxville, TN; March, 1997), it was estimated that treating a 1,000-lb cow once with ivermectin or doramectin would cost approximately $6.95. At a contemporary market price of $0.75/lb for ungraded calves, an additional 9.27 lb at weaning would be required to cover the cost of cow treatment.[23] The same market data were used to calculate that a 1.88% increase in conception rate would recoup the costs of similarly deworming a 100-cow herd and maintaining the extra calves to market weight.[23]

Although increased milk production by beef cows in response to anthelmintic treatment has not been demonstrated conclusively, the potential profitability of modest improvements is appealing. Suckling calves efficiently convert milk-to-meat at a ratio of 2.3:1 to 2.8:1, and increased milk yield has substantially greater value when marketed as weaned calves (Table 2).

Table 2. Economic comparison of the potential value of a 40-lb increase[a] in milk production by dairy cows vs. beef cows.

	Dairy	Beef
Cost of treatment[b]	$4.81	$3.88
Value of 40-lb increase	$5.60[c]	$12.00[d]
Added value	$0.79	$8.12

[a]Hypothetical quantity for purposes of illustration only
[b]Based on cost of fenbendazole (5 mg/kg) for a 1,400-lb dairy cow or 1,000-lb beef cow, plus $1.50/head for labor
[c]Based on $14.00/cwt for raw milk
[d]Based on average 2.5:1 conversion of milk to meat by suckling calves and $0.75/lb for ungraded, weaned calves, March, 1997

Suckling Calves

Parasitologic Characteristics

Beef calves acquire nematode infections as soon as they begin to sample forage,[24] and worm numbers and egg counts increase gradually until weaning. Total worm numbers at weaning are modest, and clinical helminth disease is very uncommon in suckling calves. *Cooperia* spp. comprise the majority of nematode populations in young calves, along with lesser numbers of *Ostertagia*. The fecal output of worm eggs from calves far exceeds that of their dams during the second half of the grazing period.[25]

Recommendations for Control

There have been very few studies to measure the effects of deworming beef calves without concurrent treatment of cows to confound the results.[3] A recent trial in Oklahoma found no added benefit from deworming cows in addition to calves.[26] Although the evidence in support of deworming suckling calves is not conclusive, the cost of treatment is relatively small.

To allow recovery of costs, suckling calves should be dewormed well before weaning. In the southern U.S., calves born during winter and spring should be dewormed in mid-summer with anthelmintics effective against arrested *Ostertagia*.[20] This timing coincides with strategic deworming of cows in the south. In northern regions, the risk of immediate reinfection is lowest during June and early July, but summer deworming may afford only temporary suppression of egg counts. Regardless of the geographic location, deworming suckling calves decreases egg counts and lowers pasture infectivity. Reduced numbers of infective larvae would benefit cattle of any age group subsequently grazing that pasture.

Economic Feasibility

Using local drug costs (Knoxville, TN; March, 1997), it was estimated that treating a 400-lb calf once with ivermectin or doramectin would cost approximately \$3.68. At a contemporary market price of \$0.75/lb for ungraded calves, an additional 4.9 lb at weaning would recover the cost of calf treatment.[23]

Stocker Calves and Replacement Heifers

Parasitologic Characteristics

After weaning, steers and heifers rely on forage to a greater extent than suckling calves, and consequently ingest far more larvae. Juvenile cattle often harbor very large parasite burdens of up to one million worms,[10] and have high egg counts ranging up to several hundred eggs per gram (epg).

In the southern U.S., climatic conditions permit many of the nematode eggs excreted onto pasture during the winter grazing period to hatch and develop into infective larvae.[5] This amplified parasitic challenge causes ubiquitous subclinical losses and frequent clinical disease in stockers and heifers.

In contrast, weaned steers and heifers in northern regions are often removed from pasture during the coldest months.[21] This management system poses fewer parasitologic challenges because confinement precludes nematode transmission.[22] Weaned beef calves of either sex remain highly susceptible to nematode parasitism until about 15 to 18 months of age.[7]

Recommendations for Control

Optimizing the economic return from parasite control in stocker calves and replacement heifers requires knowledge and planning. The primary objective for juvenile cattle is to limit their exposure to infective larvae. In southern regions, this is accomplished by preventing stockers from contaminating pastures with additional worm eggs.[27] Thus, the traditional practice of deworming weaned calves in the autumn prior to winter turnout is an indispensable first step because it prevents immediate contamination of pastures. However, the numbers of infective larvae on autumn pasture are moderate to high,[5] so substantial reinfection occurs shortly after turn out. Furthermore, pasture infectivity remains high for the duration of the winter grazing period, and may increase relatively as forage supplies diminish. For these reasons, a single treatment at turnout rarely provides adequate protection for the duration of the stocking season.

For maximal benefit, anthelmintic treatment at weaning must be combined with other measures.[28,29] The optimal recommendation is to turn dewormed calves out onto the cleanest winter pasture available. Ideal venues include fields that have not been grazed since early summer or pastures occupied by alternate species such as horses, sheep, goats, or deer. The usual practice of grazing stockers on pastures recently shared with their dams is less than ideal because cow-calf pastures represent a source of moderate infection. The most undesirable circumstance is to turn stockers out onto a pasture that was just grazed by another cohort of juvenile cattle.

In the northern U.S. and Canada, it is sufficient to deworm immature cattle once when they enter winter confinement with an anthelmintic that is effective against arrested *Ostertagia* larvae. If northern calves and heifers are maintained on pasture through winter, they face constant reinfection from persistent larvae. At least northern larval numbers do not increase over winter, as they can in southern regions

A single treatment of stocker calves at autumn turnout may not always be cost-beneficial.[30] Added production benefits are likely to result from a second deworming, but the timing of treatment is critical. In order to suppress new egg production, supplemental deworming should be performed three weeks after treatment with most anthelmintics currently approved for beef cattle in North America,[21] five weeks after treatment with ivermectin, or six to eight weeks after using doramectin or moxidectin (*Canada only*).[31] Alternatively, a single ivermectin sustained release bolus could be administered at autumn turnout to provide continuous protection for the subsequent 135 days.[32]

Economic Feasibility

The cost of deworming a 500-lb stocker calf twice with ivermectin or doramectin in Tennessee was estimated at \$8.45. Using contemporary livestock prices, this expenditure could be recovered by an additional 11.27 lb of weight gain at the end of the stocking period.[23] The use of ivermectin sustained release boluses at turnout is more expensive, approximately \$14.00/head, but this expense could be recouped by an additional 18.7 lb of gain.[23]

The economic feasibility of additional (i.e., >two) suppressive dewormings is debatable. Extra anthelmintic treatments do not guarantee larger economic returns. In theory, suppressive

deworming inevitably reaches a point of diminishing returns where more money is spent on anthelmintics than would have been lost to parasitism.

Conclusions

The prospects for cost-beneficial parasite control are clearly better for some classes of beef cattle than for others. It is apparent that effective parasite control in stocker calves and replacement heifers has great potential to increase profitability, but the single dose traditionally administered at weaning/turnout is often insufficient to guarantee a positive economic return.

By comparison, there are scant data to recommend or oppose deworming of suckling calves, but the cost is minimal and lowered pasture infectivity is a likely benefit.

Anthelmintic treatment of beef cows is dogma in many circles, but its economic feasibility remains problematic. This paper expresses skepticism because much of the justification for cow deworming is based on flawed science, and its greatest proponents are commercial entities with vested interests. The beef industry in North America needs and deserves current and objective information generated by well-designed trials in diverse geographic locations. Performance responses should be subjected to rigorous economic analysis.

If future research proves cow deworming to be unequivocally beneficial, we still will not understand how a temporary respite from small numbers of parasites can result in substantial, long-term improvements in the performance of a relatively immune host. Production advantages are particularly unexpected when treatments are administered at traditional times which permit rapid reinfection. Incontestable proof of cost-beneficial parasite control in beef cows will stimulate further research to dissect the mechanisms of subclinical parasitism.

Definitive recommendations must await the results of more field trials and additional basic research. Until then, veterinarians can enhance the efficiency of cow deworming by recommending strategic treatments to postpone reinfection, and by improving overall herd management.

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