Endoparasites of Cattle: Diagnosis and Assessment of Infections and Prevention and Control From Now to the Foreseeable Future

J.C. Williams, *MS, PhD*
Department of Veterinary Science
Louisiana Agricultural Experiment Station
LSU Agricultural Center
Baton Rouge, LA 70803-6002

Abstract

Gastrointestinal nematode infections remain as an important limiting factor in productivity of cattle. Questions concerning endoparasites of cattle continue in spite of substantial advances in understanding of infection and disease processes, availability of highly effective anthelmintics and delivery systems, and general means of preventing and controlling such infections. Current information on the parasites, effects on the host, recognition and diagnosis of parasitism, transmission and epidemiology, and means of prevention and control are reviewed. Near total reliance on modern broad spectrum anthelmintics worldwide has hindered acceptance and implementation of prevention and control measures integrated with grazing management. Present and future development and use of anthelmintics is dependent on resolution of problems associated with threats of drug resistance, host tissue residues, and environmental ecotoxicity. Projected practical availability of potential alternative methods of control, e.g., vaccines, breeding for host resistance, nematode growth regulators, and biological control agents, is still undetermined.

Questions concerning endoparasites or internal parasites of cattle continue to exist in spite of substantial advances in understanding infection and disease processes, availability of more potent and persisting anthelmintics and delivery systems, treatment strategies and general means of preventing and controlling such infections. The major questions raised by producers and veterinarians alike are how is economically important parasitism recognized or diagnosed, what is the real impact of such parasitism on cattle productivity and performance, and is treatment at all, or some systematic form of treatment cost effective. Most questions center around treatment and are concerned with when and at what intervals cattle of different age classes should be treated and what product should be used. Answers to such questions should be simple and straightforward, but they are complex because of great variability in cattle, animal and pasture management systems, nutrition, and climate-geographic factors (Hawkins, 1993).[1] The object of this report is to update information on parasite control and to consider present and future questions associated with cattle endoparasitism.

Perspectives on Endoparasitism in Cattle

Cattle of all ages, but particularly young and growing cattle, are affected by a diversity of internal parasites. Among these are the roundworms or Nematodes which are primarily parasites of the gastrointestinal tract (the lungworm *Dictyocaulus viviparus* is included), liver flukes (Trematodes), tapeworms (Cestodes), and protozoans, the Coccidia. Prevalence of internal parasites varies considerably throughout the country and intensity is dependent primarily on temperature and moisture. Under conditions in most southern regions long grazing seasons fostered by abundance of moisture and warmth, favor almost year-round potential for infection. Periods of greatest infection risk occur during autumn and again from late winter through spring. Length of grazing seasons are more restricted in northerly climates or those marked by cold winters, but substantial and increasing infection risk occurs from spring to autumn. Such a simplistic division of north and south or cool versus warm climate is in no way intended to define the varied conditions that exist for the major cattle raising areas of the country. Subtle or greater differences in seasonal prevalence or incidence of particular genera may occur, for example, between costal plains and rather proximal areas of higher elevation, in rangeland of varied elevations, or in regions where continental weather systems blend. Extensive movement of young cattle to midwest and western states for backgrounding further complicates regional parasite prevalence.

Under grazing conditions, it is the rule to encounter mixed infections with several species of nematodes as well as with other parasites indicated earlier. All of the internal parasites can be of economic significance at one time or another, however, because of cosmopolitan distribution throughout the country, the numbers of worms of different species that affect cattle, and the individual and collective damage that they cause, the roundworms or nematodes are considered most important.

The serious cattle producer today generally has a high level of understanding of factors that can cut into efficiency and profits in production. Many of these are aware of internal parasitism and take appropriate measures, just as they do for other disease threats, however, many others underestimate or totally ignore effects of internal parasitism on cattle productivity and general herd health. Under conditions of low parasite infection risk management such as with low stocking densities on permanent or improved pastures, rangelands, and high levels of nutrition in feedlots, it is often difficult to demonstrate that control measures will provide for actual or statistically different levels of productivity. Nevertheless, under most circumstances in which cattle production is highly intensified and internal parasites are present in an environment that favors their propagation, it is most often likely that productivity can be cost-effectively enhanced or substantially improved by parasite prevention and control measures.

The Roundworms or Nematodes

Several genera and species of nematodes are commonly found in cattle throughout the United States as indicated by material in Table 1 (Gibbs and Herd, 1986).[2] Many of these have been detected only sporadically, but a standard roster of common species are routinely encountered. Largest infections are usually found in weanling and yearling beef cattle and in dairy replacement heifers. The abomasum is the site of *Ostertagia ostertagi*, the brown or medium stomach worm, considered to be the most harmful and economically important parasite of cattle in all temperate areas of the world. Additional notes will be made later on seasonal variation in development of this parasite which can result in serious disease or productivity losses. There are some who contend that there has been over emphasis on importance of this parasite during the last 20 years, and some of the contention may be warranted. One contention is that importance of other damaging nematodes in some sections of the country are neglected because of emphasis on *O. ostertagia*. The other species cited are *Nematodirus* and to some extent *Cooperia*. Most certainly, in areas of the country where such problems have been encountered, greater attention is needed, as well as further, detailed documentation of comparative susceptibility of *Nematodirus* and *Cooperia* to ivermectin and benzimidazole anthelmintics. None of this detracts from the fact that *Ostertagia* is the major parasite of cattle through much of the country. Over emphasis of importance of

Table 1. Nematode Parasites of Cattle in the Continental United States.

SPECIES	LOCATION IN HOST	INTERMEDIATE HOST	DISTRIBUTION
Haemonchus contortus	Abomasum	None	General
H. placei	Abomasum	None	General
H. similis	Abomasum	None	South
Ostertagia bisonis	Abomasum	None	CO, MT, WY
O. lyrata	Abomasum	None	CA, FL, GA, LA, MI, NC, ME
O. Ostertagi	Abomasum	None	General
O. orloffi	Abomasum	None	CO, WY
Trichostrongylus axei	Abomasum	None	General
Gongylonema verrucosum	Rumen, omasum, abomasum	Dung beetles	South
Trichostrongylus colubriformis	Small intestine	None	South
T. longispicularis	Small intestine	None	CA, FL, GA, LA, MI, OK
Cooperia bisonis	Small intestine	None	MT, OK, WY
C. mcmasteri	Small intestine	None	General
C. oncophora	Small intestine	None	North
C. pectinata	Small intestine	None	South
C. punctata	Small intestine	None	Southeast
C. spatulata	Small intestine	None	FL, GA, MS
Nematodirus helvetianus	Small intestine	None	General
N. spathiger	Small intestine	None	General
N. filicollis	Small intestine	None	General
Bunostomum phlebotomum	Small intestine	None	General (east)
Capillaria bovis	Small intestine	None	General
Toxocara vitulorum	Small intestine	None	LA, MS, OH, OK, TX, WI
Strongyloides papillosus	Small intestine	None	AL, GA, KS, LA
Trichuris ovis	Cecum	None	General
T. discolor	Cecum	None	AL,FL,GA,ID,LA,MD
Oesophagostomum radiatum	Cecum, colon	None	General
Chabertia ovina	Cecum, colon	None	CO, OK, WY
Thelazia gulosa	Eye	Faceflies	KY
T. skrjabini	Eye	Faceflies	KY
Setaria labiopapillosa	Peritoneal cavity	Mosquitoes	General
Stephanofilaria stilesi	Abdominal skin	Hornflies	General
Onchocerca bovis		Blackflies	IL, MD, MO, TX, VA
Dictyocaulus viviparus	Trachea, bronchi	None	General

From: Gibbs, H.C. and Herd, R.P. 1986.[2] Vet. Clin. N. Amer.: Food Animal Practice, 2(2):211-224.

the parasite and its effects during the last several years could have occurred as a result of misinterpretation or confusion about regional epidemiological data or extrapolation of such data to regions in which prevalence of *Ostertagia* is low.

Also present in the abomasum are *Trichostrongylus axei*, the stomach hairworm, and *Haemonchus* sp., the large stomach worm or barber pole worm. Worms of the intestinal tract include several species of *Cooperia*, *Nematodirus* spp., the hookworm, *Bunstomum phlebotomum*, *Strongyloides papillosus*, *Trichostrongylus colubriformis*, the nodular worm *Oesophagostomum radiatum*, and the whipworm, *Trichuris* sp. The lungworm, *D. viviparus*, is found in the large and smaller air passages of the lungs. Nearly all of the worms are rather small and delicate, ranging from a fraction of an inch to more than an inch in length.

Results of surveys and other studies of apparently healthy cattle (beef and dairy cows, yearling steers, replacement heifers, and calves) generally reveal infection levels of 80% and greater as indicated by fecal egg counts and postmortem examination. As mentioned earlier, level of parasitism is greatest in young cattle; adult beef and dairy cattle generally show little evidence of nematode infection or disease unless stressed by nutritional deficiency or other diseases.

Means by Which Nematodes Can Affect Productivity

Exact mechanisms for pathophysiologic effects and consequent productivity losses caused by nematode parasites are not well understood. Different nematodes may penetrate and migrate in tissue, suck blood or otherwise cause small hemorrhages, cause mucosal erosions, or incite formation of nodules. The stomach worm (*Ostertagia*) can extensively destroy vital secretory glands of the abomasum, resulting in loss of serum proteins, reduced acidity, and diarrhea. *Haemonchus*, also in the abomasum, is an avid blood sucker as is the hookworm, *Bunostomum*, in the small intestine. Other worms of the intestinal tract (*Cooperia, Nematodirus, Trichostrongylus,* and *Oesophagostomum* can all cause significant damage to the intestinal mucosa even when present in small to moderate numbers. The lungworm may cause severe disease and deaths, particularly in young stock, primarily from effects of pneumonia, asphyxiation, and secondary bacterial infection. Because many of these worm species are present in cattle at the same time, their individual, but more importantly, their collective damaging effects can be considerable. The above is only an outline of the gross and obvious damaging effects as demonstrated by histopathology; the indirect or systemic effects are less understood.

For a long time it was thought that the primary effect of nematode infection on the host was interference with digestion and malabsorption of nutrients. Considering basic functions of the gut and the mechanical and possibly chemical changes inflicted by parasites, the association would appear to be appropriate. However, there appears to be much more involved (Holmes, 1987).[3] As indicated, many of the effects are local and probably involve inflammatory mediation produced by tissue damage in the vicinity of the parasites. Other changes reflect loss of cellular function such as parietal cell damage in the abomasal mucosa or cellular junctions (*Ostertagia*) resulting in increased permeability. Rapid development of some of these changes in response to infection of the gastrointestinal tract has suggested parasites directly or through secretions, locally affect host function.

Other changes in the host, e.g., disturbances in feed intake, protein metabolism, and fluid balance, reflect systemic responses to infection. Hormonal changes appear to be the underlying mechanism for many of the alterations in host function, but have not been clearly identified. Generalized body wasting, and muscle protein depletion are common clinical signs associated with a variety of pathologic conditions in addition to those caused by parasites. A possible role of systemically-active mediators (interleukins) is currently being investigated. One that has received attention is interleukin-1, which is known to have a variety of effects including muscle wasting, increased liver protein synthesis, and anorexia (Holmes, 1987).[3] In both nitrogen metabolism and energy metabolism, the main effect of nematode parasitism appears to be a lowering of the efficiency by which digested and metabolizable energies are used for fat and protein synthesis. The major reason for the specific effects on feed conversion over and above effects on intake appears to be related to disturbances in post absorptive nitrogen energy metabolism. These disturbances may be related to changes in protein metabolism as a consequence of excessive leakage of blood and interstitial fluid into the gut (Gibbs, 1987).[4]

Recognition - Diagnosis of Nematode Parasitism

A few years back, a veterinary parasitologist commented on a subject that is widely known, but about which, little can be done. The reference was made in relation to sheep parasitism, but has direct application to cattle nematodes also. His comment was about the fact that nematode parasite populations are most often over-dispersed in their hosts, i.e., over half the parasites are usually found in less than half of the host population (Barger, 1985).[5] This fact might suggest that treatment or other means of control might be most effectively utilized in the smaller fraction of animals harboring high levels of infection and the lesser parasitized animals might be passed over. This information is great, but there is no practical method of identifying the heavily parasitized from those that are not. In a sense this reflects the entire situation of recognition or diagnosis of nematode parasitism.

Recognition of nematode parasitism, whether it be in the form of a disease outbreak or inapparent (subclinical) parasitism and reduced productivity in a herd is a key factor in any approach to prevention and control. The situation must be understood before planning an approach. Clinical signs of parasitism such as progressive weight loss, diarrhea, rough hair coat, bottle jaw, anemia, and dehydration, are all too familiar. However, in many cases, it is necessary to rule out the possibility of diseases other than parasitism, including nutritional deficiency. Effects of nematode parasitism may go unnoticed except with careful observation. In the case of very large herd size, detecting problem cases would be even more difficult. Effects of parasites that may go unnoticed until times when cattle are worked include inefficient feed utilization, delay in attainment of breeding age, poor conception rates, depressed milk production, and lighter calves at weaning, more susceptible to parasitism and other diseases. In the case of *O. ostertagi* infections at least, evidence has been demonstrated that the parasite has a non-specific immunosuppressive effect in young cattle so far as further infection with *O. ostertagi* is concerned. Additionally, it was considered that this immunosuppression might lead to a generally increased susceptibility to diseases other than nematode parasitism (Wiggin and Gibbs, 1989).[6] Although there is little documentation of increased susceptibility to disease in parasitized cattle or reduced morbidity in treatment of such cattle, one report indicated lower calf mortality, reduced incidence of clinical coccidiosis, and lower morbidity due to respiratory disease in calves treated for parasitism compared with untreated calves (Bohlender, 1988).[7]

Besides early recognition of parasitism in individual cattle or a herd, which can help in reducing loss and preventing continued contamination of pasture with worm eggs, evaluation of general management and grazing history and weather factors is important. Nematode parasitism is clearly associated with certain grazing practices and can be controlled by avoiding or altering these practices. Having one group of calves follow a previous group of infected calves on the same pasture is an example. Another example could be the introduction of new and infected cattle onto premises not previously affected by parasitism problems. Services of a veterinarian should be considered a necessity to fully understand the nature of a given problem or more particularly, to advise on steps which would assure maintenance of good herd health and preclusion of losses due to parasitism.

Besides visual and communicative inspection of animals, premises and management practices, many food animal practitioners rely on fecal examination-egg counts and post mortem examination when available, to assess parasitism status of a herd or individual animals. Regardless of cause of death, necropsy examination can at least present any pathology due to parasitism in the gastrointestinal tract or lungs or presence of various worm species, and may confirm parasitism as a primary or accessory cause of death in animals suspected of being parasitized to one degree or another.

Fecal Examination as a Means of Diagnosing Parasitism

Fecal examinations or egg counts as a laboratory aid in diagnosis of parasitism are widely used in research, but are also extensively used by veterinarians in food animal practice. The method is time-honored and has to be taken for what it is, considering the many factors that can affect the egg count. A variety of techniques are used. Most involve clarification (screening) of a fecal suspension and centrifugation-flotation of worm eggs, coccidial oocysts, and lungworm larvae in some liquid medium of sufficient specific gravity. Some use may be made of a direct fecal smear on a microscope slide while others may make use of commercial kits which involve flotation, but are intended for use with dog or cat feces. The latter two methods are inadequate based on egg dissemination in the large mass of bulky cattle feces.

Counting and identification of parasite eggs or larvae is a limited, but useful qualitative/quantitative technique for detecting and estimating the presence or degree of parasitism in animals. It should always serve only as an adjunct means of diagnosis in association with other observations. Performed on a repetitive basis on the same animals (groups) over time as in research, the method has substantial value in tracing the course of infections, but even in this case, egg counts must be interpreted with caution following statistical analysis and consideration in association with other parasitological and production values. Although the one time sampling and examination of large numbers of cattle may be of value in surveys or demonstration of presence of nematode infections, it is the one time sample in which limitations of the method are most prevalent. Factors affecting results would include quality (rectal or random ground sample) and handling of the sample, type of method used, and developmental stages of worm populations. Differentiation of nematode eggs is no simple matter. Ranges of fecal egg counts, expressed in terms of eggs per gram of feces, have often been equated in textbooks and other information sources with levels or degree of parasitic infection or disease. Threshold ranges of such values have also been used to indicate whether treatment was warranted or not. The good or usefulness of such suggestions is questionable. The bottom line of low or high fecal egg counts means low or high **pasture contamination** with eggs and consequent continuing and possibly increasing levels of the infection source. Thus, magnitude of fecal egg counts does not always serve as an accurate indicator of impact of parasites in cattle. Adult cattle generally have counts ranging from zero to low. However, based purely on weight of feces passed daily, they can serve as a significant contributor to pasture contamination. Even for younger cattle such as calves and yearlings, and for factors cited above, any positive egg count should be included in plans for prevention and control to maintain infections at a low level.

It can be safely assumed in regions such as the southeast and south central United States, that nematode parasitism in cattle is a fact of life and without some form of effective prevention and control, losses in productivity or deaths will occur. In other regions, however, for example in the upper plains and many western states, where nematode parasitism is considered to be minimal or unimportant, conditions should be evaluated to determine if nematode parasitism merits prevention and control measures.

Transmission of Nematode Infection to Cattle

Adult male and female worms of various genera inhabit different parts of the gastrointestinal tract. After mating, female worms produce eggs which are passed out in feces onto the pasture. In the case of the lungworm, eggs hatch in the gut and first stage larvae are passed in the feces. Hatching of eggs and development and survival of infective larvae are highly dependent on temperature and moisture. All processes are rapid in warm weather and slowed during cooler weather. High temperature and desiccation in summer and subfreezing temperature in winter can effectively kill off eggs and larvae on pasture and this often results in reduced parasite transmission during these periods. *Ostertagia*, for example, does not survive well on pasture under hot and dry conditions, but can survive overwinter even under snow cover. Other nematodes such as *Haemonchus* and *Oesophagostomum* do best during warm weather.

Infective larvae on pasture grass are swallowed with forage by grazing cattle. In the case of the hookworm, *Bunostomum*, and the intestinal threadworm, *Strongyloides*, infective larvae penetrate host skin in infection. Larvae of these worms travel by the blood to the heart and lungs, are swallowed, and then mature in the intestinal tract. Development of larvae to the 3rd or infective stage can occur as quickly as 7 to 14 days during optimal conditions, but may be delayed for several weeks in colder weather. Once larvae reach the infective stage they can survive for several months, i.e., from autumn through winter in warm temperate climates and from spring through autumn in cool temperate climates. This fact clearly emphasizes how, under continuous contamination of pastures by infected cattle, large levels of larval contamination accumulate. Treatment may temporarily stop pasture contamination, but it does not erase existing larval contamination on pasture. Only time and natural attrition of larvae will take care of this. There is no known practical means of killing larvae on pasture, but investigators in Europe and Australia are exploring means of biological control using nematode-trapping fungi (Gronvold, *et. al.*, 1989).[8]

After infection, most cattle nematodes develop to the adult stage in 2 to 4 weeks. Others such as *Oesophagostomum* and *Bunostomum* require 6 to 8 weeks. Major damage occurs during the period of larval development to the adult stage. Therefore, with a total life cycle, from egg to egg, requiring from 6 to 12 weeks (2 to 3 weeks minimally on pasture and 2 to 8 weeks in cattle) during much of the year, it is possible in warmer climates for infections to recycle several times during long grazing seasons and somewhat less in shorter grazing seasons in cooler climatic zones. With constant daily infection occurring in grazing cattle, worm burdens can increase rapidly.

Ostertagia ostertagi - Inhibition of Larval Development

Throughout the country the medium stomach worm presents a problem different from the other nematodes because of seasonal variation in its life cycle pattern. Weather conditions of the south from late spring through early fall are adverse to survival of infective larvae of this parasite and consequently little or no infection occurs during the period. However, the parasite population does not die off, but spends the period of adverse weather in an inhibited or arrested early larval stage in tissues of the abomasum. The *Ostertagia* infection and disease pattern is closely tied in with age classes of cattle and different seasons as described below.

During late fall through winter and particularly in early spring in the south, cattle near weaning age and up to 14-16 months of age can be affected by type I *Ostertagiasis*. This is the time of year that is basically optimal for development and survival of infective larvae on pasture. When infection occurs the worms develop promptly to the adult stage in the normal time span of about 3 weeks. With heavy infection, the young cattle can be severely affected, showing profuse diarrhea and rapid weight loss. It is also during spring that most of the *Ostertagia* larvae on pasture become conditioned by weather factors to undergo inhibition of development once ingested by cattle. This process presumably occurs in the several weeks preceding the onset of hot and dry or wet weather of summer that kills off larvae on pasture. During the inhibited state (pre type II *Ostertagiasis*), the larval worms cause no problems. However, the inhibited worms will begin to mature to adults usually in August and September, a time when the worst part of summer weather is past. In the maturation process, the worms increase in size causing massive destruction of digestive tissue of the stomach. This form of disease is called type II *Ostertagiasis*; its harmful effect is similar, but far more serious than type I disease. Type II disease is seen most commonly from September - November and usually only a small portion of a herd is affected. Yearling steers greater than 16 months of age and replacement heifers are most often affected. First or second calving heifers may be particularly susceptible under some conditions. It is not unusual to see the condition in older cows and bulls. Large numbers of inhibited larvae, accumulated in stomach tissue since spring, can mature at intervals in the fall causing a long and drawn out disease process which may result in death with or without treatment.

In northern portions of the United States the inhibition pattern of *O. Ostertagi* is different. Larvae become inhibited in development during late autumn grazing and persist this way in stomach tissue through winter. As a result type II disease occurs from late winter into spring and type I disease in younger cattle occurs during summer and autumn. In the absence of documented research, the type of *Ostertagia* pattern which exists in some parts of the country remains unknown. In areas such as the central plains and in states across the center of the country from the Mississippi River to the Atlantic, the time of larval inhibition and disease types have not been defined.

A problem in the past has been the older anthelmintics such as thiabendazole and levamisole were effective against adult worms, but not against inhibited larvae of the medium stomach worm. These drugs were effective in controlling type I *Ostertagiasis* in winter and spring in the south or during summer in the north, but ineffective in killing inhibited larvae and controlling type II *Ostertagiasis*. Newer anthelmintics are effective against inhibited larvae and will be discussed in a later section.

Prevention and Control of Nematode Parasitism in Cattle

Eradication of worms is virtually impossible, but prevention and control of infection should be a major component of cattle herd health programs. The major aim of effective parasite control is to keep infections as low as possible in order to minimize any interference with production. Effective control must be looked upon not as a single approach, but as an integration of different complimentary components. In broad outline these components in control are: grazing management, judicious and planned use of efficient anthelmintics, and through them, enhancing the immunity capability of cattle to resist infection (Brunsdon, 1980).[9] Means of applying these components of control in livestock operations are not complex, but on a worldwide basis, acceptance and implementation have been slow. A primary reason for the slow or poor acceptance of integrated control schemes or programs is that livestock producers have come to expect and rely almost exclusively on broad spectrum anthelmintics to effectively control nematode parasites. Anthelmintics are cheap in comparison to other animal husbandry costs and tied in with aggressive sales promotion by drug companies, have fostered a "drench gun" approach in many producers, whereby opportunistic or diagnostic treatment has been common (Waller, 1993).[10] However, for the present, the foreseeable future, and on into the 21st century, a number of problems becloud current use of anthelmintics as a sole approach to nematode control. An international symposium held during the spring of 1992 in Ohio was centered on the effect of ivermectin usage in livestock on the environment, i.e., effect on non-target organisms in the environment (Herd, *et. al.*, 1993).[11] Environmental impact, tissue residues, and drug resistance in parasites are three major issues or concerns for which sustainable parasite control schemes must be developed and implemented. Such schemes would integrate a range of techniques to minimize anthelmintic use while maintaining high levels of profitability (Waller, 1993).[10] In a review of control strategies for parasites in livestock, (Herd, 1993)[11] reported that surveys have shown that livestock owners commonly fail to get good advice on parasite control, follow inefficient programs, and waste a great deal of money in such efforts with little return. Based on results of a large survey of anthelmintic treatments in England (Michel *et. al.*, 1981),[12] (Herd, 1993)[11] further indicated that most common errors in anthelmintic utilization were: drug choice, timing of treatments, unnecessary dosing of some age classes of cattle, non-utilization of available information on parasite control, and no clear idea of the purpose of prophylactic treatments. He considered that such mistakes in the United States are more costly because of the much larger cattle population. This does not take away from the fact that there is a great deal of planned and purposeful consideration given to animal and pasture management and anthelmintic administration for parasite control by serious cattle producers and/or their veterinary advisors. By means of pure common sense or with good information many cattlemen equal and even exceed the best recommendations for achieving parasite control through management and use of anthelmintics. It is just a question of more widespread application of practical control measures at all levels of cattle production.

Grazing Management

Prevention of parasitism is seldom planned into grazing management, however it does merit serious consideration and caution should be observed in what pastures are grazed by different age classes of cattle. Pastures considered to have lowest levels of parasite contamination (as judged by knowing whether infected animals were previously on the pasture) should be reserved for younger, most susceptible stock (weaners, stockers, replacement heifers). Reduced pasture contamination can result from a number of practices: pasture vacated for several weeks in summer for hay production, pasture grazed exclusively by older dry cows (low egg counts and less pasture contamination than with young cattle) for several weeks, alternate use of crop land or rested pasture planted in annual forages, and a choice not commonly available in this country, alteration of different host species (e.g., sheep and cattle) on the same pastures for several month intervals. Since younger, susceptible cattle generally have highest levels of infection and produce heavy pasture contamination, one group of young cattle should not follow another such group in the same pasture. An example in this context is related to pasture on which calves are weaned. In spring calving cow-calf herds, calves can develop large worm burdens and egg counts which begin about 2-3 months after birth. Pasture contamination usually increases during summer into autumn (calves reinfected from their own increasing pasture contamination) and is likely highest around weaning time (September-November). The large accumulation of contamination on the pasture up to weaning time can result in greatly reduced, but still substantial residual or overwintered numbers of larvae on this pasture in the following late winter-spring. When cows produce the next year's calves on the same pasture, a ready source of infection is available for the new calves and the cycle continues. A frequent question concerns the use of short interval pasture rotation in parasite control. Such regular rotation in no way reduces infection risk, but may actually increase the risk. When animals are returned to a contaminated pasture occupied 1 to 3 weeks earlier, numbers of larvae reaching infectivity and protected by a growing dense forage, could be substantially increased. This circumstance is different from the earlier indicated practice when pasture is mowed and parasites are rendered more susceptible to heat and desiccation. Another exception would be intensive or controlled grazing operations where cattle at very high stocking rates are moved from one pasture cell to another at intervals of a few days. It is assumed in this management system that land used is essentially free of parasite contamination and cattle are treated for parasites prior to entering the system.

Anthelmintics

Development and licensing of highly efficient, broad spectrum anthelmintics over the last 30 years and especially during the last 12 years has been of immense benefit in reducing losses to parasitism in cattle. However, as earlier indicated, there has been a large tendency to consider anthelmintics as the sole or primary means of control almost to the exclusion of overall good management and constant provision of good nutrition. The primary purpose of anthelmintics **is not to cure sick animals**, whether mildly or severely ill, but to **reduce levels of pasture contamination** and consequently to prevent heavy infection and such episodes of illness or reduced productivity. Reduced pasture contamination with the eggs-larvae of parasites is most effectively accomplished by some **systematic timing** of anthelmintic use, tied in with good management. With irregular treatment or only at times when the herd or individual cattle look like they need treatment, it is already too late and a waste of time, labor, and cost of drug.

The advantage of systematic use of anthelmintics is that it can be timed at least partially to mesh with some management procedure such as change of pasture or a seasonal working of the herd. Rather than systematic use, the more commonly accepted term for true preventive prophylactic anthelmintic administration is strategic treatment, meaning that treatment is based on an informed plan of attack to maximize effect of treatments.

The best of anthelmintic compounds are only minimally effective in extended parasite control when treated cattle are returned to pastures that are heavily contaminated with infective larvae. Nearly all anthelmintics presently available will remove worms from the animal over a period of a few days after treatment and this effectively prevents parasite egg shedding on to pasture for two to three weeks. The anthelmintic activity of the avermectin product, ivermectin, extends for two to three weeks rather than just a few days for some worm species. However, on heavily contaminated pasture, cattle are readily reinfected upon cessation of the anthelmintic action and adult worms will again be present in two weeks or more.

A total of eight anthelmintics are currently licensed and available for use in the United States and one of these, Clorsulon (Merck & Co., Inc.), is exclusively for liver flukes. Only a passing note will make reference to these compounds as their availability is generally known and a detailed update on specifics of them was given (Corwin, 1992)[13] in the Proceedings of the 27th World Buiatrics Congress and 25th American Association of Bovine Practitioner's Conference at Minneapolis. The two older compounds thiabendazole (Merck) and levamisole (Pittman-Moore) are still widely used, particularly the latter. Both compounds continue to have relatively high levels of efficacy at the highest recommended dosages against most of the common nematode species in cattle with exception of *O. ostertagi* (Williams *et. al.*, 1994).[14] Morantel tartrate (Rumatel®, Pfizer) has been available for a number of years and has activity similar to thiabendazole and levamisole. The 3 major benzimidazole compounds fenbendazole (Hoechst-Roussel), albendazole (SmithKline Beecham) and oxfendazole (Synex) have a similar range of high efficacy against cattle nematodes, including inhibited larvae of *Ostertagia*, and albendazole also has flukicidal activity. Lastly, ivermectin (Merck) is the only avermectin class of compound available and has broad levels of high efficacy against both endoparasites and ectoparasites. The variety of formulations for each product marketed by the manufacturers are well known including drenches, pastes, gels, pour-ons, injectables, mineral mixes, and molasses mineral blocks.

Improved Resistance to Parasites Through Management and Anthelmintics

The third component of integrated control of cattle nematodes, improved resistance or immunity to infection, as stated earlier along with grazing management and judicious use of anthelmintics, is one not readily defined, but is provided by comprehensive implementation of the other two components. Up to about a year of age cattle have little resistance to nematode infections. However, from this age, they can rapidly develop a strong immunity to several worm species and their effects. Nematodes included are mainly intestinal species - *Cooperia, Nematodirus, Bunostomum, Oesophagostomum* and to a lesser extent, *Haemonchus*, in the abomasum. Rapid immunity can also develop against the cattle lungworm if young calves are not exposed to overwhelming infections. The primary exception is *O. ostertagia*; cattle do not show much resistance to this parasite until they reach 18 months of age or slightly older. One can readily understand that if grazing management provides relatively low levels of pasture contamination and a continuous high level of nutrition to mother cows and their calves preweaning or to weaner-yearling cattle and systematic anthelmintic treatments are given to maintain low worm burdens in cattle and pasture contamination, young cattle develop a strong immunity to nematode infections. This may sound like Utopia, but it does happen.

Strategic Treatment

Strategic treatment means that young cattle must be treated up to 2 to 3 times at given intervals prior to and during periods when development and survival of nematode free-living stages are particularly favored by seasonal weather conditions. For most effective usage it is necessary to have precise epidemiological information on seasonal patterns of nematode parasitism for a given region. Unfortunately this is not available everywhere. As a last resort one can rely on extension information that relates to grazing seasons in areas that are predominant warm or cool temperate climatic zones; periods of peak infection risk generally run parallel with periods of highest forage yield and quality. All of the newer anthelmintics are suitable for effective strategic control programs and even the two older products, thiabendazole and levamisole, have been used successfully (Williams, *et. al.*, 1988).[15] Basically, the intervals between the 2 or 3 treatments are determined by the time it takes reinfecting nematodes from pasture to reach sexual maturity and full egg production. This may be as little as 3 weeks for some species (Cooperia), but 4 to 6 weeks for most others. Persistence of drug action after treatment is another factor which can extend intervals. All the drugs except ivermectin have killing activity of only 2 to 4 days; ivermectin activity is high against most species for 7 to 14 days and longer against others such as the cattle lungworm. Thus, treatment intervals with ivermectin can be slight longer. Predominance of some worms species with greater pathogenicity than others may also enter into treatment interval determination. Since a major aim of responsible anthelmintic use is to minimize the number of treatments, one night ask why 2 to 3 treatments are given during a relatively short time period. First, strategic treatment as outlined here is meant to essentially hit hard for a portion of a critical period, i.e., to remove worm populations from cattle before pasture infection increases and to maintain populations in cattle and on pasture at low levels. Second, strategic treatment should not be confused with suppressive treatment in which animals may be treated for parasites at intervals of 2 weeks to monthly over long periods of a year. This practice has been common with sheep, goats and horses and has resulted in widespread drug resistance. Third, **strategic treatment is intended almost exclusively for young, most susceptible** pastured cattle, i.e., beef calves from weaning through stocker development, including beef replacement heifers through the first and possibly second calving, and dairy replacement heifers. Although some investigators believe that adult beef and dairy cattle do not require anthelmintic treatment because of a high degree of immunity to parasites (Herd, 1988),[16] the writer believes that all age classes deserve some attention, depending on circumstances, for systematic parasite control. In the case of adult cattle, treatment at least once a year may be applicable, namely at some point shortly before calving. Additionally, use of the most expensive products is not a necessity. It is difficult to determine the percentage of producers that treat nursing calves at least once and there is no availability of economic data to warrant the practice, however, a single treatment in late spring-early summer could be cost effective in higher weaning weights particularly in regions of high infection risk as calf worm population accumulate toward weaning time. Young bulls are often ignored and because of sex-related susceptibility should be treated, perhaps even strategically as other similarly aged cattle. Under circumstances where animals are confined as in barns, drylots or feedlots, a single therapeutic treatment at the time of confinement is all that is necessary, especially when the cattle are fresh off of pasture and intended for finishing.

Times for strategic treatments will differ based on variations of nematode seasonal epidemiology in the northern or cool temperate regions and in warm or southern temperate climatic regions.

Strategic Treatment in Cool Temperate Regions

Application of strategic control is basically simpler in regions characterized by long cold winters and shorter grazing seasons than in warm temperate environments. With winter as a restricting factor both to pasture grazing and development of parasite eggs and larvae, cattle can remain essentially free of infection if treated prior to winter. Strategic treatment begins in spring when cattle are turned out to pasture. With no pasture contamination occurring during winter, the infection source is composed of larvae that have survived over winter. Levels of pasture contamination are generally low, but with improving weather conditions, the overwintered larvae on pasture and any residual infections in cattle serve as the starting point for proliferating infections and pasture contamination during summer. The period of infection risk extends from late April - early May to October or about 6 months.

In countries throughout northern Europe (Nansen, 1993)[17] and in northern areas of this country (Herd, 1993), it has been found that 2 or 3 anthelmintic treatments spaced over intervals of a few weeks from time of turnout and into the grazing season, very effectively control parasitism for the remainder of summer and fall grazing. Other approaches in northern Europe have included a treatment in mid grazing season (July) and movement then to pasture with little or no infection risk or late spring tournout (to allow for disappearance of overwintered larvae) with single or strategic treatment given at turnout time.

Strategic Treatment in Warm Temperate Regions

Development of strategic treatment programs for prevention and control of nematode parasites in warm temperate regions of the southern United States, southeastern Australia, and the lower part of South America (southern Brazil, Uruguay, and Argentina) is more challenging than for conditions in cool temperate zones. The warm climate zones are characterized by longer grazing seasons and near year round availability of nematode infection. A common seasonal prevalence in all locations is that infection risk increases during fall and winter reaches highest levels in spring. In comparison to cooler climatic zones, the effective period of infection risk extends from late September to June (March to December in Australia and lower South America) or about 9 months. The long period of major and increasing infection risk which extends from late September through April (about 7 months) is what makes control of any form difficult; the long survival of larvae on pasture under favorable weather conditions often exceeds reasonable time intervals for strategic treatment. As in the United States, treatment approaches in the other warm temperate zones may be intensive, systematic, or sporadic as cattle appear to need treatment. However, strategic treatment programs in Australia consisting of 2 or 3 treatments at weaning and at intervals of a few weeks have been found to be successful in reducing the spring increases in levels of parasitism (Anderson, *et. al.*, 1983).[18] Concentrated strategic treatments beginning at weaning in the fall have not been widely investigated in the United States, but some trials with the morantel sustained release bolus (Hawkins, *et.al.*, 1985)[19] or 2 treatments at weaning, followed by grazing on small grain pastures (Craig, *et. al.*, 1982)[20] have provided high levels of parasite control and gains.

For a number of years in Louisiana, a modified form of strategic treatment was found to produce excellent results in controlling infections with *O. ostertagia* (including inhibited larvae) and other nematodes and yielded excellent gains in yearling beef cattle. The control approach utilized, was based on the traditional fall and spring treatments used by many producers with addition of a late winter treatment. In contrast to traditional strategic treatments given at 2 to 3 short intervals or a few weeks from weaning time, the Louisiana approach consisted of 3 treatments: at weaning in October or November, in late February, and in May to mid June. This program of treatment with intervals of three and a half to four months was based on extensive epidemiological data on nematodes of cattle in Louisiana (Williams, *et. al.*, 1987).[21] Rationale of the program was initial removal of large worm burdens at weaning with the first treatment. Timing of the second treatment in late winter was for general removal of parasite species acquired after the first treatment, but particularly to remove *O. ostertagi* adult worms and lungworm. The *O. ostertagi* acquired during winter infection are the population primarily responsible for pasture contamination in late winter and spring which can result in large accumulations of inhibited larvae in cattle. Omission of this treatment with some experimental groups resulted in much larger accumulation of inhibited *Ostertagia* larvae. The third treatment in late spring was again for general removal of all nematode species, but especially for any inhibited *O. ostertagi* established in cattle after the second treatment. Experiments conducted yearly from 1982 through 1986 indicated continuous advantages of this treatment approach over fall and spring treatment only in significant ($P<0.05$) parasite reduction and gains (Williams, *et. al.*, 1989).[22] Fenbendazole at 5 mg/kg was used in one experiment and ivermectin at 200μ/kg was used in two experiments. In the first such trial, thiabendazole at 110 mg/kg given in two doses over a 2-week period at weaning was the fall treatment and this was followed by single doses of levamisole at 6 mg/kg for the midwinter and spring treatments.

In later experiments between 1989-1992, the long interval approach was compared with true strategic treatments, i.e., concentration of 3 ivermectin treatments at weaning (October) followed by two more at 6-week intervals with or without a fourth treatment in the following spring. Results of this comparison indicated that strategic close interval treatments in fall-winter with or without spring treatment were similar or less effective than the 3 long interval treatments in parasite control and growth promotion (Williams and Broussard, 1993).[23]

Concluding Remarks

Basically there are no widely recognized directions or recommendations that apply to control of cattle nematodes in the United States. Those that exist or have been publicized by universities, pharmaceutical companies, etc., certainly do not apply to every management system or age class of cattle. However, as greater understanding of parasite epidemiology is achieved, there is promise for improved utilization of excellent anthelmintics and implementation of these into existing or altered management systems.

Anthelmintic treatment, especially strategic treatment, will remain as the mainstay of nematode control for the foreseeable future. Two new anthelmintics with broad spectrum endo-, and ectoparasitic activity and persistent activity similar to ivermectin are currently in the licensing stage. Additionally, it is expected that rumen/reticulum devices that deliver low daily doses of anthelmintic for near total prevention of nematode infection for up to 5 months will be available in the next few years. This concept of parasite control is not new, but great advances in uniformity of continuous dosage and sharp cessation of release make the system revolutionary. Because parasite control might be reduced to a single annual occurrence, savings in labor cost alone, might be a major advantage along with convenience and assurance of effective treatment (Anderson, 1985).[24] However, such advantage must be weighed along with possible disadvantages. Possibilities of rapid development of drug resistance have been suggested, but it has also been considered that this form of treatment might actually reduce chances of drug resistance especially with new technology that ensures total release time less than the maximal life span of parasitic free-living stages, infrequent use of devices, constant high release rate to produce a very high parasite kill and rapid decline of release rate to zero.

There is presently little evidence for the existence of drug resistance in cattle nematodes. The problem is quite substantial for nematodes of sheep and goats worldwide and a recognized, but lesser problem in horse nematodes. Consequently, everyone involved in cattle production and control of nematode parasitism should be aware of the potential threat and measures necessary to avoid selection of nematode populations for resistance. The major selection process is overuse of anthelmintics generally and overuse of the same class of compounds over protracted time periods. Strategic treatment is concentrated treatment, but over relatively short time periods and different chemical classes of drugs could be alternated in the same or different years.

Three major areas have been indicated as present day and certainly future problems to be dealt with as concerns chemotherapy of parasitic infection as we know it. As indicated earlier, these are the threat of drug resistance, tissue residues in animals, and problems of ecotoxity. These problems will undoubtedly be resolved, but ongoing research is investigating alternative means of control. There will be continuing effort to determine better ways of using existing drugs, such as through strategic treatment. Costs of development are ever increasing, but new drugs will be developed and engineered to meet current and projected regulatory restrictions and also to be more targeted and selective in parasite control (Waller, 1993).[10] With the consideration that anthelmintics may be of less importance at some future time than they presently are, a number of alternative approaches for parasite control have been under investigation for a number of years, but a projection as to when these may be of practical use is undetermined. These approaches include: development of worm vaccines, breeding of hosts for worm resistance, nematode growth regulators and biological control agents such as bacteria, viruses, protozoa and most notably, predatory fungi (Waller, 1993).[10]

References

1. Hawkins, J.A. Economic benefits of parasite control in cattle. *Vet. Parasitol.* 1993; 46:159-173. 2. Gibbs, H.C. and Herd, R.P. Nematodiasis in cattle. Importance, species involved, immunity, and resistance. *Vet. Clin. N. Amer.: Food Anim. Pract.* 1986. 1986; 2:211-224. 3. Holmes, P.H. Pathophysiology of nematode infections. In: W.H.D. Leaning and J. Guerrero (Editors) The Economic Impact Parasitism in Cattle. Merck AGVET, Rahway, NJ, pp. 29-33. 4. Gibbs, H.C. The effects of gastrointestinal nematodes on digestion and energy metabolism in calves. In: W.H.D. Leaning and J. Guerrero (Editors), The Economic Impact of Parasitism in Cattle. Merck AGVET, Rahway, NJ, pp. 45-48. 5. Barger, I.A. The statistical distribution of trichostrongylid nematodes in grazing lambs. *Int. J. Parasitol.* 1985; 15:645-649. 6. Wiggin, C.J. and Gibbs, H.C. Studies of the immunomodulatory effects of low-level infection with *Ostertagia ostertagi* in calves. *Am. J. Vet. Res.* 1989; 50: 1764-1770. 7. Bohlender, R.E. Economics of deworming beef cattle. *Vet. Parasitol.* 1988; 27:67-71. 8. Gronvold, J., Henriksen, S.A., Nansen, P.. Wolstrup, J. and Thylin, J. Attempts to control infection with *Ostertagia ostertagi* (Trichostrongylidae) in grazing calves by adding mycelia of the nematode-trapping fungus *Arthrobothays* oligospora (Hyphomycetales) to cow pats. J. Helminth. 1989; 63:115-126. 9. Brunsdon, R.V. Principles of Helminth Control. *Vet. Parastiol.* 1980; 6:185-215. 10. Waller, P.J. Towards sustainable nematode parasite control of livestock. *Vet Parasitol.* 1993; 48:295-309. 11. Herd, R.P. Control strategies for ruminant and equine parasites to counter resistance,

encystment, and ecotoxicity in the USA. *Vet. Parasitol.* 1993; 48:327-336. 12. Michel, J.F., Latham, J.O., Church, B.M. and Leech, P.K. Use of anthelmintics for cattle in England and Wales during 1978. *Vet. Rec.* 1981; 108:252-258. 13. Corwin, R.M. Effective parasite control for cow-calf programs - an update on effective anthelmintic usage. *Proc., XVII World Buiat. Cong.* and *XXV Amer. Assoc. Bovine Pract.* 1992; 2:266-269. 14. Williams, J.C. and Broussard, S.D. Comparative efficacy of levamisole, thiabendazole and fenbendazole against cattle gastrointestinal nematodes. *Vet. Parasitol.* 1994 (submitted). 15. Williams, J.C., Knox, J.W., Marbury, K.S., Kimball, M.D., Scheide, S.W. and Snider, T.G. Effect of strategic anthelmintic treatment and pasture management on productivity and control of nematode parasites in weaner-yearling beef cattle. *Res. Vet. Sci.* 1988; 45:31-40. 16. Herd, R.P. Control strategies for ostertagiasis. *Vet. Parasitol.* 1988; 27:111-123. 17. Nansen, P. Current and future prospects for control of ostertagiasis in northern Europe - examples from Denmark. *Vet. Parasitol.* 1993; 46:3-21. 18. Anderson, N., Donald, A.D. and Waller, P.J. Epidemiology and control of parasitic gastroenteritis of cattle in the temperate climatic zone. In: N. Anderson and P.J. Waller (Editors), The Epidemiology and Control of Gastrointestinal Parasites of Cattle in Australia. Div. Anim. Health, CSIRO, Melbourne, pp. 47-63. 19. Hawkins, J.A., Evans, R.R. and Newby, T.J. Field efficacy of a morantel sustained release bolus for control of gastrointestinal nematodes in yearling steers. *Vet. Parasitol.* 1985; 17:229-238. 20. Craig, T.M., Spitzer, J.C. and Leps, R. The effect of anthelmintic treatment on growth of beef heifers on temporary winter pasture. *Southwest Vet.* 1982; 34:1-4. 21. Williams, J.C., Knox, J.W.., Marbury, K.S., Kimball, M.D., Baumann, B.A. and Snider, T.G. The epidemiology of *Ostertagia ostertagi* and other gastrointestinal nematodes of cattle. *Parasitology.* 1987; 95:135-153. 22. Williams, J.C., Knox, J.W., Marbury, K.S., Swalley, R.A. and Willis, R.E. Three treatments with ivermectin in year-long control of gastrointestinal nematode parasites of cattle. *Vet Parasitol.* 1989; 33:265-281. 23. Williams, J.C. and Brussard, S.D. Comparison of treatment strategies with ivermectin for control of gastrointestinal nematodes of cattle in Louisiana. *Proc. Ann. Meet. Amer. Assoc. Vet. Parasitol.* 1993; p. 21. 24. Anderson, N. Controlled release technology for the control of helminths in ruminants. *Vet. Parastitol.* 1985; 18:59-66.