Introduction

There are many important diseases of sheep and goats, but none pose a greater threat to the health of sheep and goats as internal parasites. Control of internal parasites is therefore of primary concern in any small ruminant health management program, and is critical to profitability. Gastrointestinal nematodes (GIN) that infect sheep and goats in the US include *Haemonchus contortus*, *Trichostrongylus colubriformis*, *T. axei*, *Teladorsagia circumcincta*, *Cooperia* spp., *Oesophagostomum*, *Trichuris ovis*, *Strongyloides papillosus*, and *Bunostomum*. Although all of these parasites can contribute to the overall problem of gastrointestinal parasitism, it is the highly pathogenic blood-sucking parasite *H. contortus* that by far is the most prevalent and important in most regions of the US, and especially in the southern states.

Diagnosis of haemonchosis is made based upon the characteristic clinical signs of anemia, submandibular anemia, weight loss, and ill thrift along with finding large numbers of trichostrongyle eggs in the feces. Female *Haemonchus* produce approximately 5,000 eggs per day and sheep/goats can be infected with thousands of these worms. This potentially results in hundreds of thousands to millions of eggs being shed onto pasture by each animal each day. Because the life cycle is so short (< 3 weeks), pastures can rapidly become very dangerous places for small ruminant animals.

The 2 other major species of importance are *Trichostrongylus colubriformis* and *Teladorsagia circumcincta*. Though in the US their importance tends to pale in comparison to *H. contortus*, both have the potential to cause significant production loss and disease. *Teladorsagia circumcincta* prefers cool climates, so is most likely to be a problem in the northern portions of the US, but is present in Virginia. *Trichostrongylus colubriformis* is intermediate in temperature preference and does well in both cool and warm climates. Both parasites cause a more classical parasitic gastroenteritis, characterized by reduced appetite, reduced weight gain and/or weight loss and diarrhea. In contrast, *H. contortus* rarely causes diarrhea. Because any one or all of these parasite species may be infecting an animal, it is important to determine which species are present before optimal control measures can be implemented.

As is the case for most parasitic diseases, haemonchosis is most severe in young animals during their first year on pasture. Lambs and kids need special attention to parasite control around the time of weaning, as these animals will be highly susceptible to parasitic disease and will be under considerable stress. Immunity to GI nematodes in goats is slow to develop and is incomplete, therefore even mature goats are at considerable risk. In contrast, mature dry ewes tend to have quite a good immunity to GIN infection. However, any one or combination of a number of factors such as poor nutrition, concurrent disease, stress, overstocking, or pregnancy/lactation can cause a loss of immunity to parasites. It is well established that ewes and does lose much of their protective immunity to GIN around the time of kidding/lambing (-2 to +8 weeks) causing the number of parasites infecting the does to increase. Subsequently, parasite egg production and contamination of the environment with
In that same class. However, drugs do differ in their potency, therefore some drugs with a lower potency are still effective in goats. A key point is that the bioavailability of these drugs is generally lower in small ruminants compared to larger livestock. Therefore, it is recommended that a 2X dose be given to goats, but the bioavailability is still lower than in sheep or cattle at the label dose. Furthermore, because of the risk of toxicity with levamisole, it is recommended that individual goats be weighed prior to treatment to determine the appropriate dose. A dose 1.5 times higher than for sheep or cattle should never be used by that route. This approach reduces the risk of toxicity and provides a margin of safety. However, even at a 2X dose, the bioavailability has important implications in the development of anthelmintic resistance.

Anthelmintics are used in the control of gastrointestinal nematodes in sheep and goats.

There are 3 primary classes of anthelmintics available for use in treatment of helminth infections in ruminants in the United States (USA): (1) benzimidazoles (BZ), (2) imidazothiazoles/tetrahydropyrimidines (I/T) also referred to as membrane depolarizers, and (3) avermectin/milbemycins (AM) (also referred to as macrocyclic lactones and macrolide endectocides). All 3 of these anthelmintic classes are broad spectrum nematocides, but spectrum against other groups of parasites varies widely. In the USA all of the anthelmintics that are labeled for use in ruminants are approved for cattle, and most of the commonly used anthelmintics are labeled for sheep; however, the number of FDA-approved drugs available for use in the treatment of gastrointestinal parasites in goats is severely limited. Currently only 4 drugs are approved for use in goats; morantel, thiabendazole (TBZ), fenbendazole (FBZ) and phenothiazine, with TBZ no longer marketed. This list is further limited in usefulness since drug resistance to benzimidazoles (TBZ, FBZ, and related compounds) and phenothiazine is very common. Other unapproved anthelmintics that are commonly used in goats include: ivermectin, doramectin, moxidectin, albendazole, and levamisole. Thus, extra-label use is an important issue in goats. In sheep, the 4 most commonly used anthelmintics; ivermectin, albendazole, levamisole and moxidectin are all FDA approved so extra-label use of anthelmintics is not a major issue for sheep. The law does allow limited extra-label use of drugs, but such use is an exclusive privilege of the veterinary profession and is only permitted when a bona fide veterinarian-client-patient relationship exists and an appropriate medical diagnosis has been made. Regardless of whether anthelmintics are used following label indications or in an extra-label manner, it is important that adequate milk and meat withholding times are stringently adhered to (Table 1).

Anthelmintics are most effective when administered orally to small ruminants and this is the preferred route of administration. Pour-on anthelmintics are poorly absorbed in small ruminants and have a very low bioavailability, so should never be used by that route unless specifically treating for ectoparasites. A recent study in cattle clearly demonstrated that orally administered avermectin/milbemycin drugs were significantly more effective than when administered by injection or pour-on. Sheep should be dosed using the appropriate label directions (all FDA approved sheep anthelmintics come in an oral drench formulation). Goats also should be treated orally only, but when using drugs in an extra-label manner in goats it is extremely important that the sheep or cattle (label) dose is not used. Goats metabolize anthelmintic drugs much more rapidly than other livestock and require a higher dosage to achieve proper efficacy. Consequently, it is recommended that goats be given a dose 1.5 – 2 times higher than for sheep or cattle. A 1.5X dose (5.45 mg/lb; 12 mg/kg) is recommended for levamisole, because a 2X dose is approaching a level that may be toxic in goats. Furthermore, because of the risk of toxicity with levamisole, it is recommended that individual goats be weighed prior to treatment to determine the appropriate dose. For all other anthelmintics it is recommended that a 2X dose be given to goats. However, even at a 2X dose, the bioavailability generally is still lower than in sheep or cattle at the label dose. This low bioavailability has important implications in the development of anthelmintic resistance.

In general, resistance to one drug in a class of anthelmintics confers resistance to all other drugs in that same class. However, drugs do differ in their potency, therefore some drugs within a class will...
be more effective than others in the early stages of resistance. However, once resistance reaches high levels it is unlikely that any drug in a given class would remain effective. Since resistance to either ivermectin or doramectin confers resistance to the other, and there are no approved formulations of doramectin for small ruminants, for most indications extra-label use of doramectin in small ruminants cannot be justified. However, doramectin injectable may be the treatment of choice for sheep scab \textit{(Psoroptes ovis)} because its longer persistence will clear the infection with a single treatment. Also, because of its longer persistence, doramectin would be preferred for prophylactic treatment against \textit{Parelaphostrongylus tenuis} in camelids. Moxidectin, a milbemycin, is a very closely related compound with similar spectrum of activity, but is more lipophilic than the avermectins and therefore has an even longer persistent activity. Moxidectin is also more potent against many nematodes and therefore will often kill worms that are resistant to the avermectin drugs. However, moxidectin resistance now is quite common as well.

It took almost 30 years (since the introduction of ivermectin) for a new anthelmintic drug class to reach the marketplace, but recently, two new classes of anthelmintic drugs have been marketed for use in sheep in many parts of the world; the amino-acetonitrile derivatives (monepantel, Zolvix®) and the spiroindoles (derquantel, Startect®). Monepantel is a broad-spectrum nematocide approved for use in sheep at 5.5 mg/lb (2.5 mg/kg). As of this writing monepantel is not yet approved in the United States, and it is unknown when or even if it will be approved and sold in the US. Additionally, it seems unlikely that Startect® will be marketed in the United States. Thus it seems that we have for the foreseeable future, making the implementation of sustainable parasite control strategies increasingly important.

**Anthelmintic Resistance: An Emerging Problem That Is Changing Our Approach For Controlling Gastrointestinal Nematodes In Small Ruminants**

Anthelmintic resistance is defined as a heritable genetic change in a population of worms that enables some individual worms to survive drug treatments that are generally effective against the same species and stage of infection at the same dose rate. In practical terms anthelmintic resistance is present in a population of worms when the efficacy of the drug falls below that which is historically expected, when other causes of reduced efficacy have been ruled out. Parasitic nematodes have many biologic and genetic features that favor the development of drug resistance. Short life cycles, high reproductive rates, rapid rates of evolution, and extremely large population sizes combine to give many parasitic worms an exceptionally high level of genetic diversity. This leads to certain individual worms having gene mutations that reduce their susceptibility to the drug. These worms then amplify themselves in the population when under drug selection.

Resistant worms can come from only two places; either they are home grown or purchased inside an animal. Amplification of resistance within a worm population to clinically relevant levels is typically a slow and gradual process, requiring numerous generations under drug selection (usually taking several to many years). Thus, from a practical perspective, the genetic phase of resistance develops slowly over time during which it is impossible to detect, but then increases very rapidly in its later phase, where it is then perceived as a clinical event. Alternatively, resistant worms can be purchased, thus bypassing the many years of worm evolution and drug selection necessary to reach high levels. Depending upon how many animals are purchased harboring resistant worms, and other management and pasture factors, treatment failures can occur practically instantly or over a relatively short period.

This has great clinical relevance because in either case, resistance can transition from
undetectable, to clinically important levels over a very short period of time. Consequently, unless a surveillance program is in place that closely monitors the effectiveness of drug treatments over time, resistance will not be noticed clinically until levels of resistance are extremely high. There is also very strong evidence for the BZ and AM classes that once resistance is diagnosed as a clinical problem “reversion” to susceptibility likely will never occur. With levamisole, there is evidence of some degree of reversion back to susceptibility, but any reversion is likely to be short-lived and of little practical benefit.

The scope and prevalence of resistance -- For many years, worms were controlled in small ruminants by the frequent use of anthelmintics, and this approach was quite effective. However, we now know that this strategy has turned out to be shortsighted and unsustainable. During the period 2002-2009 two studies were performed investigating the prevalence of anthelmintic resistance on 80 sheep and goat farms in the southern and mid-Atlantic states. In the southern states (2002-2006) *H. contortus* from 45 (98%), 25 (54%), 35 (76%), and 11 (24%) farms were resistant to benzimidazoles, levamisole, ivermectin, and moxidectin, respectively. Resistance to all 3 classes of anthelmintics was detected on 22 (48%) farms, and resistance to all 3 classes plus moxidectin was detected on 8 farms (17%). Thus on almost 20% of all farms tested, resistance was detected to all available anthelmintics; a situation referred to as “Total Anthelmintic Failure”.

In the mid-Atlantic region study performed a few years later (2007-2009) the prevalence of moxidectin resistance was twice as high at 47% of farms. Similar severe problems with anthelmintic resistance are occurring worldwide.

**Diagnosis of Anthelmintic Resistance**

Given the high levels and spectrum of anthelmintic resistance that have been documented, before developing an effective control program for *H. contortus* or any other GIN parasite on a farm, it is extremely important to know the resistance status of worms on that property. Presently, this can be done only 2 ways: (1) by performing a fecal egg count reduction test (FECRT); or (2) by performing an in vitro larval development assay (LDA). The FECRT is presently the most commonly used means of determining whether an anthelmintic is effective on a particular property, and has the advantage that it can be done on any farm with any drug. An alternative to the FECRT is the DrenchRite LDA however; the test is not suited for in-clinic use and can only be performed in a specialized parasitology diagnostic lab. A single DrenchRite LDA can measure and detect resistance to benzimidazole (BZ), levamisole (LEV), and avermectin/milbemycin (AM) anthelmintics from a single sample. In the DrenchRite assay, nematode eggs are isolated from feces and placed into the wells of a microtiter plate containing growth media and varying concentrations of anthelmintic. The concentration of anthelmintic required to block development of nematode larvae to the third-stage is correlated to the in vivo efficacy of the drug.

In deciding which test to perform there are a number of factors to consider. The DrenchRite LDA has advantages relating to veterinarian/farmer convenience and amount of information acquired from the test. To have a DrenchRite LDA performed, a veterinarian needs only to express-mail a pooled fecal sample from goats/sheep on a farm to the laboratory performing the test. Data from the DrenchRite LDA provides a quantitative measurement of the level of resistance to all 3 major drug classes (including moxidectin). The level of resistance to each drug can also be monitored over time, thus providing information on the impending development of resistance even where the drug remains effective. One limitation of the DrenchRite LDA is that very few labs have the expertise to perform it.
Another is that when results show border-line resistance it is not possible to be sure if the drug will yield satisfactory efficacy or not.

In contrast, the FECRT provides a direct measurement of the effectiveness of the anthelmintic, though the observed efficacy is subject to high variability once it falls below 95%. Furthermore, the FECRT is performed only at a single dose (the label dose [sheep] or 1.5-2X the label dose [goats], thus the results will only tell if you the drug is effective or not at that dose; it provides no warning of emerging resistance until the drug fails. The FECRT also requires much more time and effort by the veterinarian, as fecal samples must be collected from individually identified animals, FEC performed, treatments applied accurately, treatment records kept and entered into a spreadsheet or other analysis program, and data analyzed and interpreted.

When performing a FECRT in sheep or goats, it is suggested that guidelines published by the World Association for the Advancement of Veterinary Parasitology (WAAVP) be used, applying practical modifications to fit the situation on the farm. It is worth noting that an updated guideline is in the final stages of preparation and should be published by the end of 2016. Briefly, groups of 15 animals that have not been treated within the past 8 weeks are randomly allocated to treatment groups and fecal egg counts (FEC) are performed (usually using the modified McMaster technique) 10-14 days after treatment. If enough animals are present on the farm, multiple drugs can be tested simultaneously. If treatment groups are smaller than 15 animals the accuracy of the FECRT may be compromised when results are in the gray borderline/suspected resistance range (85-95%), however, if efficacy is very high (>97%) or very low (<80%) interpretation is pretty straightforward, even with much fewer animals.

**Smart Drenching**

Despite the occasional development of new anthelmintic classes, history clearly demonstrates that the development of resistance is almost certain to outpace the introduction of new drugs. Clearly then, major changes need to be made in the way that nematode control is practiced. It is no longer acceptable for veterinarians to view GIN parasite control in terms of a “deworming program”. Over the past decade a paradigm shift has occurred in how GIN parasite control must be viewed and practiced. Anthelmintics can no longer be viewed as an inexpensive management tool to be used with little thought to maximize animal productivity, but instead must be viewed as an extremely valuable and limited resource. We must balance our desire for simplicity and ease with the reality that effective long-term control of GIN will only be possible if anthelmintics are used intelligently with prevention of resistance as a goal. To address this issue, a concept referred to as ‘Smart Drenching’ has been introduced. Smart drenching is an approach whereby we use the current state of knowledge regarding host physiology, anthelmintic pharmacokinetics, parasite biology, dynamics of the genetic selection process for resistance, and the resistance status of worms on the farm to develop strategies that maximize the effectiveness of treatments while also decreasing the selection of drug resistance. With regard to *H. contortus*, which is almost always the most important species of GIN in small ruminants in the USA, one of the most important aspects of smart drenching is a selective treatment approach based on the use of FAMACHA®.

There are some specific strategies that can and should be used to maximize the effectiveness of treatments and to prevent the development of anthelmintic resistance. Some of these are directly related to the concept of smart drenching, while others relate to general management practices. The implementation of these strategies may vary considerably depending upon: (1) the primary parasite
species that needs to be controlled, (2) the level and spectrum of resistance already present in a region (or farm), (3) regional/local management systems that are used, (4) farm-specific pasture and management systems, (5) type and quality of animal handling system, and (5) available labor. However, there are some general guidelines that are useful in almost all circumstances and these are listed below. Finally, FAMACHA® must be regarded as a centerpiece of any worm control program where Haemonchus contortus is the primary problem.

FAMACHA® -- Selective rather than whole-herd treatment: Selective treatment is a critical component of a program designed to delay the development of anthelmintic resistance. Selective treatment works by maintaining refugia in the parasite population; defined as the portion of the worm population that escapes drug selection. This unselected refugia, provide a pool of drug sensitive genes, thus diluting the frequency of resistant genes in a population of worms. In practical terms with regard to small ruminant parasites, refugia would be all the eggs and larvae already on pasture at the time of treatment, and all the worms in those animals that are left untreated with anthelmintic. In general, the larger the refugia, the slower the evolution of resistance. If treatments are given at a time of the year when few infective larvae are on pasture, (early in grazing season or during drought), then eggs shed by the resistant worms that survived the treatment are not greatly diluted. Thus resistant worms will make up a significantly larger proportion of the next generation of worms infecting the animals.

Worm burdens are not evenly distributed in animal populations; 20-30% of the animals harbor about 80% of the worms. These 20-30% are primarily responsible for contaminating the environment with infective larvae for all the other animals. By identifying those 20-30% and treating only those animals, we could control the parasites, save money by reducing the number of treatments given on a herd basis, and greatly lessen the selection for resistance by maintaining an adequate refugia.

Several methods have been tested for infections with non-hematophagous species (T. circumcincta, Trichostrongylus spp.), but these will not be addressed here, as in the USA H. contortus is almost always the most prevalent and important species infecting small ruminants. In the late 1990’s a clinical on-farm system called FAMACHA® for classifying animals into categories based upon level of anemia was developed in South Africa. Since anemia is the primary pathologic effect from infection with H. contortus, this system can be an effective tool for identifying those animals that require treatment. To use FAMACHA®, farmers observe the color of ocular mucus membranes and compare this color to a laminated card with illustrations of eyes from sheep at different levels of anemia. The card is calibrated into 5 categories: 1 = red, non-anemic; 2 = red-pink, non-anemic; 3 = pink, mildly-anemic; 4 = pink-white, anemic; 5 = white, severely anemic. Though initially developed for use in sheep, FAMACHA® has also been validated for goats. Prior to its introduction to the USA, the ACSRPC performed a validation study of FAMACHA® on both sheep and goat farms, finding that the system worked very well under southern USA conditions. Based on this study a set of guidelines was developed for its use.

Results of that study indicated that treatment can be safely withheld until animals score as 4s or 5s as long as animals are in good body condition and good overall general health, are examined frequently (e.g., every 2 weeks) and good husbandry is used to identify animals in need of treatment (e.g., unthrifty, anorexic, lagging behind, bottle jaw) between FAMACHA® examinations. However, it is recommended that this scheme should only be applied to adult animals. Lambs and kids have comparatively small blood volumes and can progress rapidly from
moderate to severe anemia. This precaution should also be extended to ewes and does during the periparturient period, since these animals have decreased immunity to GIN and high nutritional demands. These and other animals that may be stressed by disease, have access to inadequate nutrition or are in poor body condition should always be treated if scored as 3s.

An alternative approach could be to treat all 3s, 4s and 5s. This will result in many more treatments being given to non-anemic animals, but will virtually eliminate the possibility that an anemic animal will fail to receive treatment. Although many more treatments will be given, significant refugia will be maintained and the evolution of anthelmintic resistance should still be slowed considerably. On farms where resistance testing shows that several drugs are still effective, treating all 3s, 4s and 5s would be a safer approach and will result in better worm control. Many animals will still be left untreated supplying a significant level of refugia.

In addition to the benefits of reducing drug costs and delaying the development of anthelmintic resistance, use of FAMACHA© can also help to improve the genetic resistance of individual herds or flocks. It has been established that host resistance to infection with H. contortus measured on the basis of FEC and PCV is a moderately heritable trait, and it has been demonstrated that the same animals tend to exhibit the highest FEC and lowest PCV on each occasion that they are measured. Importantly, data from recent investigations examining the heritability of resistance and resilience of Merino sheep to infection with H. contortus indicate a high heritability for the clinical estimates of FAMACHA© scores. Since it can be expected that the same animals will require frequent treatments, and this trait of parasite susceptibility will be passed to the next generation, FAMACHA© can be a very useful tool for identifying animals to be culled. Removing the most susceptible animals from the breeding pool each year will have the long-term effect of improving the overall innate genetic resistance and/or resilience of the herd or flock to H. contortus. Such progress could never be made using traditional anthelmintic treatment approaches.

While it appears simple and straightforward to examine ocular mucous membranes and assign animals to the proper category, experience in South Africa and here in the USA has shown that training and experience is required to use this system effectively. It is critical that users of FAMACHA© receive proper training and understand the risks of incorrect use of this system (e.g. animal mortalities) and necessary precautions that should be taken. Of particular importance is training in the proper technique for examining the ocular mucous membrane. If poor technique is used, then results will be suboptimal. It must also be remembered that there are several other important gastrointestinal (GI) nematodes that cause disease besides Haemonchus contortus. FAMACHA© is only useful to detect animals in need of treatment due to infections with H. contortus and cannot be used to detect worm infections with these other GI worms. It is important not to forget about Trichostrongylus colubriformis and Teladorsagia circumcincta, and this is an important reason to periodically monitor FEC even when using FAMACHA©.

FAMACHA© is distributed under the auspices of the South African Veterinary Association. Professor GF Bath (project coordinator for FAMACHA© in South Africa) has required that distribution in the US can be made only through the ACSRPC (acsrpc.org) via the laboratory of Dr. Kaplan (University of Georgia), and that FAMACHA© cards are only to be sold directly to veterinarians or other trained animal health professionals. These individuals are expected to provide training in the proper use of the FAMACHA© system prior to re-selling the cards and must sign a statement indicating their acceptance of this responsibility.

**Know the resistance status of the worms infecting the herd:** With the prevalence of resistance so high, it is critical that anthelmintic efficacy be determined on each farm, and be monitored every 1 to 2
years. Even when the prevalence of resistance is high, there are some farms where drugs are still effective. These farms would gain considerable benefit by using these drugs. Therefore, drugs should not be excluded from use just because resistance is common. On the contrary, one does not want to use drugs that are ineffective. The only way to determine this is to perform a test. Tests need to be performed regularly, as levels of resistance can rapidly escalate and cross the clinical threshold from effective to ineffective.

**Keep resistant worms off the farm:** Anthelmintic resistant worms can come from only two sources; either they are home grown or they are purchased. Unfortunately, resistant worms come free of charge with new additions; this is a very common means of spreading the drug resistance problem. It is therefore extremely important for sheep and goat producers not to buy and introduce resistant worms to their farm. All new additions to the herd or flock should be quarantined in a dry lot (without any grass) or on concrete and aggressively dewormed upon arrival. The current recommendation is that once new additions are acclimated to the new surroundings they should then held without feed for 24 hours and dewormed sequentially on the same day with moxidectin, levamisole, and albendazole. After 14 days a FEC or fecal float should be performed and the animal should only be allowed to enter the herd if the fecal is negative. If this triple-drug treatment fails to remove all parasites then the animal needs to be kept in confinement until no more eggs are shed. If a 14-day quarantine is not possible, animals should be confined to pens for a minimum of 48 hours following treatment before being moved to pasture. However, this is a risky approach. After the animal is released from quarantine, it should be placed on a pasture previously grazed by sheep or goats (large refugia) and should NEVER be placed on a clean or safe pasture that has not had sheep or goats on it in the recent past.

**Administer the proper dose:** Every dose of anthelmintic should be given with the goal of maximizing the killing of worms. Several studies have demonstrated that sheep/goat producers often underestimate the weight of their animals and therefore underdose their animals. Underdosing exposes worms to sublethal doses of drug, which increase the selection for resistance. This is an especially high risk practice in goats who metabolize the drugs much more rapidly than other livestock. Animals should be weighed individually or dosed according to the heaviest animals in the group (except for levamisole in goats where overdosing can be risky) and dosing equipment should be frequently checked for accuracy.

**Utilize host physiology to maximize drug availability and efficacy:** Anthelmintic efficacy is directly related to the duration of contact between drug and parasite. With all other factors being constant, by simply extending the contact time, efficacy of many anthelmintics is improved. When orally treating a ruminant it is critical that the full dose lodges in the rumen. Once in the rumen, the duration of drug availability as it is absorbed from the rumen and flows to more distal sites of absorption is largely dependent on the flow-rate of the digesta. Since rumen volume remains relatively constant, there is an inverse relationship between feed intake and digesta residence time. Simply restricting feed intake for 24 hours prior to treatment decreases the rate of digesta transit and increases drug availability and efficacy. This effect has been demonstrated in both pharmacokinetic studies and field efficacy trials where this strategy significantly increased the efficacy of fenbendazole against benzimidazole field-resistant strains of GI nematodes. Withholding of feed should always be done when using a BZ drug and is helpful when using ivermectin. With moxidectin and levamisole it is not necessary to withhold feed as it is unlikely that an increase in efficacy will be seen.

Proper technique when drenching animals is also very important. All anthelmintics
administered orally should be delivered over the back of the tongue. Presenting a drench to the buccal cavity, rather than into the pharynx/esophagus, can stimulate closure of the esophageal groove with significant drench bypassing the rumen.\textsuperscript{20} Absorbed drug concentrations may be higher initially, but are of such short duration that efficacy is reduced.\textsuperscript{6} Special dosing syringes and extenders that attach to regular syringes are sold by several sheep supply companies and should be routinely used. Without any additional cost or effort, these 2 recommendations have the potential to significantly improve drug efficacy, thereby prolonging the useful life of today’s anthelmintics and should be used as a matter of course.

**Split and repeat dosing:** As mentioned above, increasing the duration of contact between drug and parasite can significantly increase efficacy. This also can be accomplished by administering 2 doses 12 hours apart. Repeat dosing can be used as an alternative to withholding feed, or even better, in addition to withholding feed. In one study, the efficacy of fenbendazole increased from 50% when administered as a single dose, to 92% when 2 doses were administered 12 hours apart.\textsuperscript{21} This approach is most likely to yield benefit when using a BZ drug. With levamisole it is recommended to wait a full 24 hr before re-dosing. Treatment with BZ drugs can be repeated for 3 days in a row as well. This may increase efficacy in the short term but also will place a very high selection pressure for higher levels of resistance.

**Rotation of anthelmintics:** Rotation is not recommended; it is an overblown concept that gives farmers (and veterinarians) a false sense that they are actually doing something worthwhile in terms of resistance prevention, when in fact it does little to slow the development of resistance. And given the high rates of resistance, it is likely that one will be rotating to an ineffective drug.

**Combination anthelmintics - dosing with two or more different drugs at same time:** This practice is highly recommended and should be used as a matter of course (see Cattle Proceedings for more details).

**Reduce the frequency of treatment through the use of sound pasture management:** Good pasture management can also go a long way in preventing resistance by minimizing the dependence on anthelmintics. Anthelmintics alone will not successfully control parasites in the face of poor management and animal husbandry. Managing pastures so that safe grazing areas are available will permit animals to be moved to a safe (low-contamination) area, reducing the number of treatments that are needed. It is important however, that the animals not be treated immediately before the move to safe pasture unless a proportion of the animals are left untreated, as treating and moving to clean/safe pasture can rapidly accelerate the development of resistance on a farm.\textsuperscript{22}

Goats are natural browsers, and parasite transmission is greatly reduced when animals are browsing because they are ingesting forage farther from the ground. Thus browse areas, particularly where there are plants growing with good nutritive value, should be used as much as possible. The numbers of animals on the farm must also be matched with the amount of pasture and the quality of the forage on that pasture. Overstocking increases the amount of fecal/larval contamination, and can often make control of *H. contortus* nearly impossible. Reducing stocking rates to appropriate levels will decrease the number of parasites that sheep and goats are exposed to and will also improve the quality and quantity of forage available to the animals. Multiple-species grazing can also be a considerable help in controlling GIN parasites. Most parasites are host-specific, thus cattle and/or horses can be co-grazed with sheep//goats, or pastures can be rotated among the various livestock species. Cattle or
horses will ingest the sheep/goat infective larvae without harm and visa versa. Using this simple biological approach can produce great benefits.

**Novel Non-Chemical Approaches**

In response to the crisis posed by drug-resistant parasites, researchers and extension personnel who have the responsibility of providing parasite control advice to the small ruminant industry have come to realize that total reliance on chemical control for parasites is no longer a viable strategy, and new innovative schemes using sustainable approaches must be implemented. There are a number of new non-chemical technologies for GIN parasite control that are being used now and will continue to become increasingly important both in the short and long term future. These include vaccines, nutritional supplementation, nematophagous fungi, bioactive forages, copper oxide wire particle boluses, and various genetic approaches. Each of these approaches provide specific benefits, however, none of these by themselves is likely to provide an answer to the problems of parasite control. Instead an integrated approach, sometimes referred to as ‘sustainable integrated parasite management’ (sIPM) that combines several of these novel methods together with limited but intelligent use of anthelmintics will be necessary. Veterinarians and small ruminant owners must be prepared to keep up to date with new developments that are certain to materialize in the coming years as these novel approaches are further developed and validated.

Therefore, at the present time we are unfortunately left with few well tested options other than good management and intelligent chemical control with anthelmintics. However, In the mean time, In response to this changing paradigm of anthelmintic use, new recommendations for parasite control have been proposed. The basis of this approach is to use the knowledge we have about the parasite, the animal, and the drugs to develop strategies that maximize the effectiveness of treatments while also decreasing the development of drug resistance. The term “Smart Drenching” is often used to describe this approach to worm control.

**Conclusion**

New novel anthelmintics will eventually be developed and sold in the future, and this will help in the short-term. However, it is almost certain that the development of anthelmintic resistance will continue to outpace the introduction of any new drugs. Consequently, the days of being able to control GIN in small ruminants using a “deworming program” by treating the entire herd/flock with anthelmintics at frequent intervals are at an end. Specific strategies are presented in this paper that can and should be used to maximize the effectiveness of treatments, while also reducing the rate with which anthelmintic resistance develops. However, a sIPM program combining multiple modalities is much more complex and difficult to implement than is a traditional “deworming program”. Due to the complexities of instituting such programs, successful implementation will only be possible with the help and active involvement of small ruminant veterinarians and other animal health professionals.

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a Rumatel® Pellets, Durvet Inc., Blue Springs, MO 64014
b Omnizole®, no longer marketed
c Safe-Guard®, Panacur®, Merck Animal Health, Summit, NJ 07901
d Feno-Drench Suspension®, no longer marketed
e Ivomec®, Merial Ltd., Duluth, GA 30096
f Dectomax®, Zoetis, Florham Park, NJ 07932
g Cydectin®, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri 64506
h Valbazen®, Zoetis, Florham Park, NJ 07932
i Prohibit®, AgriLabs, St. Joseph, MO 64505
j Zolvix®, Novartis Animal Health, Inc., Basel, Switzerland

k Jackson-O’Brien, submitted
l Dr Jennifer Gill, Microbial Screening Technologies, Smithfield, Australia

m for more information on submitting a sample for DrenchRite LDA see acsrpc.org, or contact Sue Howell at University of Georgia at jscb@uga.edu
n New guidelines for FECRT are currently under development by a WAAVP subcommittee, and are expected to be published in the near future. These will then supersede the recommendations referenced in Coles et al. (1992)
o see FAMACHA® Information Guide at www.acsrpc.org
p Information and inquiries regarding obtaining FAMACHA® cards are available at acsrpc.org or by sending an email to famacha@uga.edu
q Additional information on novel approaches to parasite control can be found at the American Consortium for Small Ruminant Parasite Control website www.acsrpc.org.