Appendix 5: Additional Resources

APPENDIX 5

ADDITIONAL RESOURCES

ABSTRACTS OF PAPERS ON GASTROINTESTINAL PARASITISM FROM ONTARIO, CANADA

This work, as well as reading other research papers and consulting with international experts, has formed the basis for the handbook. We have attempted to make it as relevant to Canadian sheep and goat producers as possible, while understanding the international context of this disease. Full papers are available on request.


In order to characterize the epidemiology of sheep gastrointestinal nematodes in organic and conventional flocks in Canada, a longitudinal study was carried out from May 2006 to March 2008 on 32 purposely selected farms in Ontario (ON) and Quebec (QC): 8 certified organic (CO), 16 non-certified organic (NCO), and 8 conventional (C) farms. On each farm, 10 ewes and 10 female lambs were selected. Farm visits were undertaken monthly during the grazing season, and twice in the winter. At each visit, individual fecal samples were taken, and pasture samples were obtained during the grazing season. In addition, body condition score was recorded for all sheep. Fecal egg counts per gram of feces (EPGs) were determined for all fecal samples, and infective larvae (L3) were identified in fecal samples (lambs and ewes separately) and pasture samples from farms. Necropsies of 14 lambs from 7 of the 23 Ontario farms were performed at the end of the grazing season in 2006. The mean EPG for year 1 (May 2006 to March 2007) was 181 (range=0-9840) and 351 (range=0-18940) for the ewes in ON and QC, respectively, and for the lambs was 509 (range=0-25020) and 147 (range=0-3060) for ON and QC, respectively. During year 2 (April 2007 to March 2008), the mean EPG was 303 (range=0-21160) and 512 (range=0-22340) for the ewes in ON and QC, respectively, and for lambs was 460 (range=0-26180) and 232 (range=0-8280) for ON and QC, respectively. Although the overall mean EPGs were not remarkably high, there were months of higher EPG such as May-June for ewes and July-August for lambs in both provinces. Pasture infectivity was highest in May-June and September. There was a general trend for the CO farms to have lower mean EPG than NCO and C farms. Fecal cultures demonstrated that the most predominant nematode genera were Teladorsagia sp., Haemonchus sp. and Trichostrongylus spp. Pasture infectivity was highest during June-July (984 L3/kg DM) in ON farms and September (mean=436 L3/kg DM) in QC farms during year 1. In year 2, the highest peak was during October in ON (mean=398 L3/kg DM) and July in QC (239 L3/kg DM). Trichostrongylus axei and Trichostrongylus colubriformis were the species most frequently identified from necropsies (36.44% and 38.26%, respectively) at the end of the grazing season in 2006, with Haemonchus contortus and Teladorsagia circumcincta being the next most commonly identified.


With increasing levels of anthelmintic resistance worldwide and a growing demand to produce more organic products, utilisation of control strategies for gastrointestinal nematodes (GIN) that minimize the use of anthelmintics becomes even more important. This study evaluated the farm-level performance of an existing predictive sheep parasite model from the United Kingdom (UK), using Canadian data. The UK model simulates the epidemiology of three major GIN species of interest (Teladorsagia spp., Haemonchus spp. and Trichostrongylus spp.) and provides a prediction about seasonal parasite levels of lambs and ewes. Model inputs were generated by using data from the first 2 years of a 3-year study (2006-2008), which examined the epidemiology of GIN parasitism in Ontario sheep flocks. Required input data included ewe parasite egg output, pasture-related information and management dynamics. Farm visits in 2006 and 2007 provided relevant data that were collected monthly during the grazing season, on six and seven occasions respectively. These data were collected from 10 ewes and 10 lambs on each farm. For 23 Ontario farms with available data, only 11 farms in 2006 and 14 in 2007 had suitable data to run in the model because the Canadian study was not specifically designed with this simulation model in mind. Observed values for faecal egg counts (FEC) were compared to the model FEC outputs and assessed using linear regression analysis. There was adequate fit between observed and simulated data for 8 of the 11 farms modelled using data generated in 2006 (F=7.55-42.66, df=10-11, R^2=0.43-0.81, p=0.021 to <0.001) and with 8 of the farms modelled using data generated in 2007 (F=5.56-35.82, df=9-11, R^2=0.36-0.82, p=0.040 to <0.001). We suggest that the poor fit between observed and simulated data for some data sets may be attributable to low-level infection on farms making regression difficult due to insensitivity of the egg count method at low values, or a pattern for immunity in ewes that contradicted the model assumptions. Required model modifications focused on accommodating the differences between UK and Canadian
management styles; specifically the practice of bringing lambs indoors for weaning which was sometimes used on Canadian farms.


Selected alternative treatments for preventing or controlling gastrointestinal nematodes (GIN) in sheep under field conditions were evaluated using a systematic review-meta-analysis methodology. Forty-three publications reporting 51 studies (21 controlled studies (CS) and 30 challenge studies (ChS)) and 85 unique treatment comparisons were included in the review. The alternative treatment categories were nutraceuticals (28 studies), breeding for genetic resistance (12), nutritional manipulation (6), homeopathies (2), administration of copper oxide wire particles (2), and biological control (1). Random effect meta-analyses (MA) and meta-regression were performed with the natural logarithm of the difference in means (lnMD) between the control and treatment groups, for fecal egg counts per gram of wet feces (FEC), worm counts (WC) or fecal egg counts per gram of dry matter (FECDM) as the outcome. Treatment effect estimates (lnMD) were back-transformed to their count ratios (CR), a relative measure of effect for controlled versus treated groups, for presentation of results.

Significant heterogeneity was observed for both CS and ChS that evaluated nutraceuticals, genetic resistance and nutrition treatments. MA of ChS that investigated nutraceuticals resulted in a significant overall CR of 1.62 (P<0.01) and 1.64 (P<0.01) for FEC and FECDM, respectively and a marginal significant CR of 1.14 (P=0.06) for WC, all favoring the treated groups. MA of CS and ChS that investigated genetic resistance resulted in a significant overall CR of 5.89 and 15.42, respectively (P<0.01), again favoring treated groups. MA of CS that investigated homeopathies with FEC as an outcome were homogenous (I²=0.0%) and resulted in a non-significant pooled CR of 1.61. ChS investigating copper oxide wire particle treatments and WC as an outcome, were homogenous (I²=0.0%) and had a marginally significant pooled CR of 1.68 (P=0.06). Publication bias was observed for CS with WC outcomes, indicating that small size studies reporting non-significant CR, were less likely to be published than similar studies that found a significant CR. In a meta-regression, randomization (6.2%) and study size (29.2%) were the main factors contributing to the total variation when the outcome was FEC, and none of the variables contributed to between study heterogeneity. When the outcome was WC, type of treatment was the only significant covariate, explaining 6% of the heterogeneity and 38.5% of the total variation. The methodological soundness and reporting of primary research in the selected studies were low. Our results indicate that from the studied alternative treatments, nutraceuticals and use of genetically resistant sheep might be more promising for control of GINs in sheep.


Cysticercus ovis, the intermediate stage of a canine tapeworm, Taenia ovis, produces cystic lesions in the skeletal and cardiac muscle of sheep, which, if numerous, will result in the condemnation of an entire carcass. In 2007 and 2008, the number of carcass condemnations due to C. ovis rose dramatically across Canada, suggesting that the prevalence of this infection on sheep farms was increasing. Trace-back of 237 carcasses condemned at Ontario provincially inspected abattoirs, between March 2009 and March 2011, revealed they originated from 133 farms across Canada. A case-control study was performed (n=40 cases, 56 controls) to identify farm-level risk factors associated with carcass condemnations due to C. ovis. Participating farms, located in Alberta, Saskatchewan, Manitoba and Ontario, were asked to answer a short questionnaire, which collected information about each farm’s geographic location and management practices. A multivariable logistic regression model revealed that farm dogs scavenging deadstock (OR=4.04; 95% CI: 1.16-14.04) and failing to dispose of deadstock (OR=11.78; 95% CI: 2.93-47.40) were significantly associated with condemnations (p ≤ 0.05).


Gastrointestinal nematodes (GIN) are a significant constraint to pasture-based sheep production worldwide. Anthelmintic resistance (AR) has been reported in most sheep-raising areas in the world, yet little is known about the AR status in Canada. This study was conducted to determine the frequency of AR in GIN in sheep flocks in Ontario, Canada. Forty-seven sheep flocks were enrolled in the study, and their level of parasitism was monitored monthly throughout a grazing season by analyzing owner-acquired fecal samples from 15 grazing lambs per flock. When the mean GIN fecal egg count (FEC) reached a threshold of 200 eggs per gram (epg), oral ivermectin was supplied to producers to check ivermectin efficacy; the reduction in mean FEC 14 days after ivermectin treatment was calculated. 'Drench failure' was defined as a reduction in mean FEC of <95%. In those flocks with apparent drench failure, researchers performed a Fecal Egg Count Reduction Test (FECRT), dividing sheep into 4 treatment groups (n=10-15): control (i.e. untreated), ivermectin, and, if sufficient numbers of animals -
fenbendazole and levamisole. AR was defined as a reduction in mean FEC <95% and a lower 95% confidence interval <90%. Larval cultures were performed on pooled post-treatment FECRT samples. Larval Development Assays (LDAs) to detect the presence of resistance to thiabendazole and levamisole were performed prior to the ivermectin drench check on pooled owner-acquired fecal samples that reached the 200 epg threshold. Approximately 89% (42/47) of the farms reached the FEC threshold of 200 epg; 93% (39/42) of these farms performed an ivermectin drench check, and 88% (34/39) of these farms had drench failure. The FECRT was performed on 29 of the 34 farms. Resistance to ivermectin, fenbendazole and levamisole was demonstrated on 97% (28/29), 95% (19/20) and 6% (1/17) of the farms tested, respectively, with considerable variability in resistance levels among farms. Haemonchus sp. was the most commonly cultured parasite from post-treatment fecal samples. LDA results for 21 farms were available; of these, 14% (3/21) and 62% (13/21) had low and high levels of thiabendazole resistance, respectively, while none of the farms exhibited resistance to levamisole. Amongst these tested farms, resistance to both ivermectin and benzimidazoles was very common. These findings strongly suggest that AR, particularly in Haemonchus sp., is a serious problem in these sheep flocks. Thus, marked changes in GI N management need to be instituted immediately to mitigate a worsening situation.


The epidemiology of the periparturient egg rise (PPER) of gastrointestinal nematodes (GINs) in sheep remains unclear, and may be influenced by the lambing season. This longitudinal study was performed to determine the effect of out-of-season lambing on the PPER in ewes in Ontario, and whether total plasma protein (TPP) and packed cell volume (PCV) were associated with the PPER. Six farms that practiced out-of-season lambing were enrolled, and sampled for three consecutive lambing seasons (winter, spring and autumn). For each lambing season, all farms were visited five times. On the first visit for each lambing season, 15-20 pregnant ewes and 15-20 non-pregnant/early gestation ewes were randomly selected. At each visit, fecal samples were collected from all selected animals and processed individually to measure GIN fecal egg counts (FECs). Blood samples were collected on three visits in each lambing period and processed to measure TPP and PCV. The ewes were classified into one of five production stages (maintenance [i.e. not pregnant], early or late gestation [<120 d and ≥120 d, respectively], and early or late lactation [<40 d and ≥40 d, respectively]) based on information collected during farm visits. Linear mixed models were developed for the TPP, PCV and logarithmic-transformed FEC (lnFEC). During the winter and spring lambing season, the FECs increased gradually over the gestation period and peaked during lactation, with these increases being larger in ewes with a low PCV (three-way interaction in the final model). In the autumn lambing season, the FECs started off higher in early gestation, and increased rapidly to peak in late gestation, particularly for animals with low PCV levels. In the TPP model, PCV and lnFEC were positively associated with TPP. During both autumn and winter lambing seasons, the TPP decreased from maintenance throughout gestation and early lactation, followed by an increase in late lactation, except for when there were high FECs. During the spring lambing season, TPP peaked at early gestation, and then decreased in late gestation, to increase more gradually over lactation. In the PCV model, PCV increased with TPP and decreased exponentially with increases in lnFEC. The PPER occurred during all three lambing seasons, and its magnitude and distribution varied with the lambing season, suggesting that the PPER in ewes depends on both environmental and animal physiological factors, an important consideration when implementing preventive parasite control strategies on sheep farms that practice out-of-season lambing.


The metacestode stage of the tapeworm, Taenia ovis, causes cystic lesions in the skeletal and cardiac muscle of sheep, which can result in the condemnation of the entire carcass. In recent years, Canadian farms have seen a marked increase in the number of condemnations due to T. ovis. Mathematical transmission models provide a useful tool for predicting parasite transmission and for evaluating the efficacy of potential control options. To date, no model has been developed exclusively for T. ovis. In the work described here, a compartmental, deterministic transmission model was developed to better understand the transmission dynamics of T. ovis on Canadian sheep farms. The model was intended to be practical, and represent the transmission of infection burdens in lambs that result in carcass condemnation, or transmission to canids. All transmission parameters were obtained from the literature or, when unavailable, expert opinion. The model incorporated each stage of the parasite lifecycle using the most probable transmission route on Canadian sheep farms; including definitive host (guard dogs), intermediate host (pastured lambs), and environment. Based on literature, the model performed as expected, and provided a reasonable estimate of parasite prevalence in lambs. In addition, modeling allowed the efficacy of potential control options to be evaluated and compared. Model simulations suggested that infection risk in market lambs could be eliminated through the regular treatment of guardian dogs every fifth week with an appropriate cestocide, or through eliminating carcass consumption by guardian dogs.

In 2011, a field study was conducted to assess drug resistance of gastro-intestinal nematodes in sheep flocks in Ontario, Canada. Benzimidazole resistance in *Haemonchus contortus* was assessed by genetic analysis of eggs; measurement of resistant allele percentages at codons 167, 198 and 200 in the β-tubulin gene was determined on pools of *H. contortus* eggs using pyrosequencing. Susceptibility to benzimidazoles in gastro-intestinal nematodes was also determined using a Faecal Egg Count Reduction Test (FECRT) and a Larval Development Assay (LDA). In total, 16 farms were assessed with the genetic test. Based on resistant allele frequencies, all of the farms (16/16) tested had benzimidazole resistance in *H. contortus*; the overall percentage of benzimidazole-resistant *H. contortus* (estimated prior to treatment using the Hardy-Weinberg formula) was 68.5%. The FECRT and LDA were performed on 11 and 13 farms, respectively. Resistance to fenbendazole was detected on 100% (11/11) of the farms where the FECRT was performed. The LDA revealed the presence of thiabendazole resistance in *H. contortus* in 92% (12/13) of the farms. Estimated percentages of resistant parasites in *H. contortus* populations obtained with the two biological tests and the genetic test were compared. The results of the genetic test were in agreement with the biological tests and confirmed that benzimidazole resistance in *H. contortus* is present in Ontario sheep flocks. Differences between the different methods of drug resistance detection are discussed in terms of cost, time and sampling.


Distributed worldwide, *Taenia ovis* infection is responsible for the condemnation of sheep carcasses in many countries. This review highlights the programme used in New Zealand to successfully control *T. ovis* in sheep, and discusses how similar approaches may be modified for use in Canada, given what is currently known about the epidemiology of *T. ovis*. The lifecycle of the parasite is well known, involving dogs as the definitive host and sheep or goats as the intermediate host. An effective vaccine does exist, although it is not presently commercially available. In New Zealand an industry-based, non-regulatory programme was created to educate producers about *T. ovis* and necessary control strategies, including the need to treat farm dogs with cestocides regularly. This programme resulted in a substantial decrease in the prevalence of *T. ovis* infections between 1991 and 2012. Historically, *T. ovis* was not a concern for the Canadian sheep industry, but more recently the percentage of lamb condemnations due to *T. ovis* has increased from 1.5% in 2006 to 55% in 2012. It has been suggested that coyotes may be transmitting *T. ovis*, but this has not been confirmed. Recommendations are made for the Canadian sheep industry to adopt a control programme similar to that used in New Zealand in order to reduce the prevalence of *T. ovis* infection.


This study investigated the overwintering survival and infectivity of free-living gastro-intestinal nematode (GIN) stages on pasture. The presence of GIN larvae was assessed on 3 sheep farms in Ontario with a reported history of clinical haemonchosis, by collecting monthly pasture samples over the winter months of 2009/2010. The infectivity of GIN larvae on spring pastures was evaluated using 16 tracer lambs. Air and soil temperature and moisture were recorded hourly. Free-living stages of *Trichostrongylus* spp. and *Nematodirus* spp. were isolated from herbage samples. Gastrointestinal nematodes were recovered from all tracer lambs on all farms; *Teladorsagia* sp. was the predominant species. Very low levels of *Haemonchus contortus* contortus were recovered from 1 animal on 1 farm. The results suggest that *Haemonchus* larvae do not survive well on pasture, while *Teladorsagia* sp., *Trichostrongylus* spp. and *Nematodirus* spp. are able to overwinter on pasture in Ontario and are still infective for sheep in the spring.


**BACKGROUND:** Anthelmintic drugs have been widely used in sheep as a cost-effective means for gastro-intestinal nematode (GIN) control. However, growing anthelmintic resistance (AHR) has created a compelling need to identify evidence-based management recommendations that reduce the risk of further development and impact of AHR.

**OBJECTIVE:** To identify, critically assess, and synthesize available data from primary research on factors associated with AHR in sheep.

**METHODS:** Publications reporting original observational or experimental research on selected factors associated with AHR in sheep GINs and published after 1974, were identified through two processes. Three electronic databases (PubMed, Agricola, CAB) and Web of Science (a collection of databases) were searched for potentially relevant publications. Additional publications were identified through consultation with experts, manual search of references of included publications and conference proceedings, and information solicited from small ruminant practitioner listservs. Two independent
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investigators screened abstracts for relevance. Relevant publications were assessed for risk of systematic bias. Where sufficient data were available, random-effects Meta-Analyses (MAs) were performed to estimate the pooled Odds Ratio (OR) and 95% Confidence Intervals (CIs) of AHR for factors reported in ≥2 publications.

RESULTS: Of the 1712 abstracts screened for eligibility, 131 were deemed relevant for full publication review. Thirty publications describing 25 individual studies (15 observational studies, 7 challenge trials, and 3 controlled trials) were included in the quantitative synthesis and assessed for systematic bias. Unclear (i.e. not reported, or unable to assess) or high risk of selection bias and confounding bias was found in 93% (14/15) and 60% (9/15) of the observational studies, respectively, while unclear risk of selection bias was identified in all of the trials. Ten independent studies were included in the quantitative synthesis, and MAs were performed for five factors. Only high frequency of treatment was a significant risk factor (OR=4.39; 95% CI=1.59, 12.14), while the remaining 4 variables were marginally significant: mixed-species grazing (OR=1.63; 95% CI=0.66, 4.07); flock size (OR=1.02; 95% CI=0.97, 1.07); use of long-acting drug formulations (OR=2.85; 95% CI=0.79, 10.24); and drench-and-shift pasture management (OR=4.08; 95% CI=0.75, 22.16).

CONCLUSIONS: While there is abundant literature on the topic of AHR in sheep GINs, few studies have explicitly investigated the association between putative risk or protective factors and AHR. Consequently, several of the current recommendations on parasite management are not evidence-based. Moreover, many of the studies included in this review had a high or unclear risk of systematic bias, highlighting the need to improve study design and/or reporting of future research carried out in this field.


A study was conducted in sheep on Canadian farms to describe the relationship between packed cell volume (PCV) or fecal egg counts (FEC) and subjective clinical parameters that may indicate the severity of parasitic gastroenteritis. Twenty-one farms in Ontario (ON) and 8 farms in Quebec (QC) were purposively selected and visited during April-May (spring) and August (summer) 2007. At each farm visit, blood and fecal samples were collected from 10 ewes and 10 female lambs; body condition score (BCS), dag score (DS), fecal consistency score (FCS) and FAMACHA score were recorded for all sampled sheep. Packed cell volume was determined for all blood samples, and FEC were performed for all fecal samples. Summary statistics and simple correlations were performed for the parameters recorded. Two mixed models with random effects at the farm level were developed; one using PCV as the response variable and another using the natural log of eggs per gram of feces (lnEPG). Finally, the residuals from both models were correlated to the covariates in the models. The mean PCV values during the spring were 29.7% and 36.7% for lambs, and 28.8% and 31.1% for ewes, in ON and QC, respectively. During the summer, the mean PCV was 32.0% and 32.8% for lambs, and 30.1% and 29.9% for ewes, in ON and QC, respectively. The arithmetic mean FEC per gram of feces (EPG) during the spring was 3 and 2 for lambs, and 1266 and 789 for ewes, in ON and QC, respectively, whereas during summer the arithmetic mean EPG was 907 and 237 for lambs, and 458 and 246 for ewes in ON and QC, respectively. Results from simple correlations indicated that PCV was negatively correlated with lnEPG (r = -0.255; r(2) = 6.5%) and FAMACHA (r = -0.312; r(2) = 9.7%), and positively correlated with BCS (r = 0.317; r(2) = 10%). LnEPG was negatively correlated with BCS (r = -0.232; r(2) = 5.4%) and PCV (r = -0.255; r(2) = 6.5%), but positively correlated with FAMACHA (r = 0.178; r(2) = 3.2%) and DS (r = 0.086; r(2) = 0.7%). Results from the models indicated that PCV and lnEPG residuals were negatively correlated with FAMACHA, FCS and almost all categories of BCS and DS, although the correlations were very low. The main results from this study suggested that none of the subjective clinical parameters evaluated were highly correlated with PCV or lnEPG and therefore were not good predictors of lnEPG or PCV on the studied farms in Ontario and Quebec.


This study compared results obtained with five different fecal egg count reduction (FECR) calculation methods for defining resistance to ivermectin, fenbendazole, and levamisole in gastrointestinal nematodes of sheep in a temperate continental climate: FECR1 and FECR2 used pre-and post-treatment fecal egg count (FEC) means from both treated and control animals, but FECR1 used arithmetic means, whereas FECR2 used geometric means; FECR3 used arithmetic means for pre- and posttreatment FECs from treated animals only; FECR4 was calculated using only arithmetic means for post-treatment FECs from treated and control animals; and FECR5 was calculated using mean FEC estimates from a general linear mixed model. The classification of farm anthelmintic resistance (AR) status varied, depending on which FECR calculation method was used and whether a bias correction term (BCT, i.e., half the minimum detection limit) was added to the zeroes or not. Overall, agreement between all methods was highest when a BCT was used, particularly when levels of resistance were low. FECR4 showed the highest agreement with all the other FECR methods. We therefore recommend that small ruminant clinicians use the FECR4 formula with a BCT for AR determination, as this would reduce the cost of the FECRT, while still minimizing bias and allowing for comparisons between different farms. For researchers, we recommend the use of FECR1 or FECR2, as the
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inclusion of both pre- and posttreatment FECs and use of randomly allocated animals in treatment and control groups makes these methods mathematically more likely to estimate the true anthelmintic efficacy.


In Ontario, Canada, widespread resistance to ivermectin and fenbendazole, the only readily available ovine anthelmintics, has been documented, primarily in Haemonchus sp. In other parts of the world, closantel has been used to control such infections; however, the drug was not currently licensed for use in Canada and the USA. A randomized controlled trial was conducted on six client-owned farms in Ontario in 2013 and 2014 to determine the efficacy of closantel (Flukiver® 5% Oral Suspension, Elanco Animal Health, 10mg/kg body weight) against ivermectin- and fenbendazole-resistant Haemonchus sp. infections in periparturient ewes and grazing lambs. Three farms were randomly assigned to treat all ewes, and three farms were randomly assigned to selectively treat individual ewes at lambing, using predetermined criteria. Fecal samples were collected from a minimum of 15 randomly selected ewes and 13 lambs per group on each farm at the time of treatment and approximately 14 days later. Trichostrongyle-type fecal egg counts (FEC) were performed using a modified McMaster technique with a lower detection limit of 8.3 eggs per gram of feces (epg). Haemonchus-specific FECs were determined by multiplying FECs by the proportion of Haemonchus sp. identified from coproculture for each farm; Haemonchus-specific FEC reductions were calculated for each farm. Twenty grazing lambs had FECs conducted monthly, and when mean monthly FECs surpassed 200 epg, all lambs were randomly allocated to either closantel, positive control (ivermectin, fenbendazole, or levamisole) or negative control groups. Pre-treatment Haemonchus-specific mean FECs ranged from 27 to 3359 epg in ewes and 0-5698 epg in lambs. Efficacy of closantel against Haemonchus sp. ranged from 99% (95% CI: 97%-99%) to 100% in recently lambed ewes on all farms in both years (total n=274 ewes), and from 99% (95% CI: 98%-99%) to 100% in grazing lambs in both years on all but one farm (total n=171 lambs). On the latter farm, a whole flock treated farm, closantel efficacy in grazing lambs was 84% (95% CI: 81%-88%) in the first year, but 100% in the second year. Levamisole was effective against overall GIN in lambs on only two farms. Ivermectin and fenbendazole resistance continued to be present, particularly in Haemonchus sp. Closantel had excellent efficacy against Haemonchus sp. over the two year study period, regardless of treatment group, and therefore should be considered one viable component of sustainable integrated parasite control programs for farms with documented anthelmintic resistance and problems with haemonchosis.


Haemonchosis is often associated with late gestation and parturition in ewes in Canada. Due to widespread concerns about development of anthelmintic resistance (AR), targeted selective treatment (TST), where individual animals are treated with an anthelmintic rather than the entire flock, is a possible strategy to control clinical signs in recently lambed ewes while still maintaining parasite refugia. Performing fecal egg counts (FEC) on individual animals is often cost-prohibitive, so indicators that identify ewes with high FEC are essential for TST programs. The study objectives were to: a) evaluate the ability of four TST indicators to identify periparturient ewes with high Haemonchus sp. FEC and b) determine appropriate treatment thresholds for statistically-significant indicators. A field study was conducted during the 2013 and 2014 lambing seasons (February-May) on three client-owned farms in Ontario with documented AR and problems with haemonchosis in ewes. Ewes were examined within three days of lambing and selected for treatment with oral closantel (10mg/kg body weight), a novel anthelmintic to Canada, if they met at least one of four criteria: a) the last grazing season was their first grazing season; b) body condition score ≥2; c) Faffa Malan Chart (FAMACHA©) score ≥3; and/or d) three or more nursing lambs. Fecal samples were collected per rectum on the treatment day from each of 20 randomly selected treated and untreated ewes on each farm. Haemonchus sp. percentages on each farm, as determined by coproculture, ranged from 53% to 92% of total fecal trichostrongyle-type egg counts. Mean Haemonchus sp. FECs were significantly higher in treated ewes (n=136) than in untreated ewes (n=103) on the day of treatment in both years (p=0.001), suggesting the indicators were suitable for identifying animals with high Haemonchus sp. FEC. A linear mixed model was fit with logarithmic-transformed Haemonchus sp. FEC as the outcome variable, the four indicators and year as fixed effects, and farm as a random effect. FAMACHA© score was the sole indicator to remain significantly associated with FEC (p=0.002). A receiver-operator curve determined that test sensitivity was maximized (92.4%) with FAMACHA© score ≥3 as the sole indicator. FAMACHA© score should therefore be included in TST programs to identify ewes requiring treatment at lambing due to Haemonchus sp.

**BOOKS AND TECHNICAL MANUALS**

Appendix 5: Additional Resources


WEB-BASED VIDEOS AND INFORMATION


SCOPS (Sustainable Control of Parasites) United Kingdom. http://www.scops.org.uk

American Consortium for Small Ruminant Parasite Control. https://www.wormx.info


Online FAMACHA© Certification. University of Rhode Island. https://web.uri.edu/sheepngoat/famacha/


FDA’s public meeting on antiparasitic drug use and resistance in ruminants and equines. Food and Drug Administration, USA. https://www.fda.gov/AnimalVeterinary/ResourcesforYou/ucm318015.htm


NADIS Animal Health Skills Parasite Forecast (model based on weather) http://www.nadis.org.uk/parasite-forecast/

Ovis Management Ltd (New Zealand) https://www.sheepmeasles.co.nz

SELECTED RESEARCH AND REVIEW PAPERS


Kenyon F, Greer AW, Coles GC et al. The role of targeted selective treatments in the development of refugia-based approaches to the control of gastrointestinal nematodes of small ruminants. Vet Parasitol 2009;164:3-11.


Larsen M. Biological control of nematode parasites in sheep. J Anim Sci 2006;84(E. Suppl.):E133-E139


