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Cooperia punctata: Effect on cattle productivity?

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ABSTRACT

Cooperia spp. have become the most prevalent parasites in United States cow/calf operations as observed in the USDA NAHMS (National Animal Health Monitoring System) Beef Cow/Calf survey in 2008. This is at least in part due to the widespread use of macrocyclic lactones that have recently been shown to have a reduced activity against these parasites. The effects of *Cooperia* spp. on cattle productivity are largely unknown. This study was conducted to assess their effect upon cattle housed under conditions found in American feedlots. Two hundred yearling calves (average weight 460 lb/209 kg) were acquired from northwestern Arkansas and northeastern Oklahoma and were vaccinated and dewormed upon arrival at the feedlot. Animals were comingled and preconditioned for approximately one month, and were fed a standard growing ration throughout the study. Calves were randomly divided into two groups ($n = 80$, infected and control) and each group was further divided into two replicate pens ($n = 40$). Calves from the two infected pens were orally inoculated with a gavage of 1×10^5 and 0.825×10^5 infective larvae of a recent isolate of *Cooperia punctata* on day 0 and 14, respectively, with the two control pens receiving a similar volume of tap water. Data collected included biweekly fecal egg counts, daily individual feed consumption and weight gain over the 60-day test period. The presence of *C. punctata* (>99% of recovered worms) was confirmed by necropsy and recovery from the small intestine on days 35 and 60 post infection (PI) in a subset of animals. Egg counts were positive by day 14 PI and remained at numbers similar to values seen in field studies. The control group gained weight 7.5% more rapidly ($p = 0.02$) than infected animals (3.24 lb/1.47 kg per day vs. 3.0 lb/1.36 kg per day, respectively). The *Cooperia*-infected calves also consumed 1.5 lb (0.68 kg) less dry feed per day than the control animals ($p = 0.02$). These data suggest that *C. punctata* has a deleterious effect on both appetite and nutrient uptake or utilization. At necropsy (days 35 and 60), the draining mesenteric lymph nodes of infected animals were increased in size and the small intestinal mucosa was thickened and covered with a thick layer of mucus in the infected animals. The most prominent histological changes in the *Cooperia*- infected animals included a moderate increase in the number of intraepithelial lymphocytes and globule leukocytes, as well as aggregates of eosinophils within the lower lamina propria. The only significant difference was an increase in the goblet cell density at day 60. Anthelmintic sensitivity/resistance of the *Cooperia* isolate used was determined by treatment of one pen of infected calves with a macrocyclic lactone and the other pen with a benzimidazole at the completion of the study. The macrocyclic lactone treatment ($n = 40$)

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did not remove the parasites (FECRT = 8.8%), while treatment with a benzimidazole was very effective (FECRT = 98.1%). This study demonstrated that *C. punctata* has a significant effect on cattle productivity, both reduced weight gain and decreased feed intake compared to controls.

1. Introduction

Cooperia spp. have become the most prevalent nematode parasite in the United States cow/calf operations as observed in the USDA NAHMS Beef Cow/Calf survey in 2008 (Stromberg et al., unpublished data). This is at least in part due to the widespread use of macrocyclic lactones that have a reduced efficacy against parasites of this genus. Macrocyclic lactones have changed the way that cattle are managed, due to their high efficacy, broad spectrum of action, and large margin of safety. Their availability led to the development of strategic parasite control programs to reduce the parasite population on pasture and thus improve overall animal productivity and increase return on investment. Parasite free status has resulted in a significant improvement in production parameters. A large (4 site) study by Ballweber et al. (1997) showed significant weight gains (0.152–0.272 kg/day) of parasite free stocker cattle when compared to controls. A study in Minnesota found that parasite free calves out gained controls by 19.3 kg and 13.2 kg in two successive years. After adjusting for birthdate and birthweight, parasite free calves demonstrated an Average Daily Gain (ADG) of 0.13 kg more than controls over the two year period (Stromberg et al., 1997).

This widespread usage of macrocyclic lactones has resulted in changes in husbandry practices, such as increased stocking rates, and a reduction in the utilization of pasture management practices to control the effects of parasitism. These changes have contributed to the selection of drug resistant helminth parasites. Resistance to benzimidazoles and macrocyclic lactones has been well documented in small ruminants (Waller, 1997). A recent study in cattle (Gasbarre et al., 2009b) demonstrated resistance in *Haemonchus placei* and *Cooperia* spp. to avermectins and milbemycin, specifically to moxidectin, doramectin, eprinomectin, ivermectin, as well as albendazole. Additionally the study found a small number of *H. contortus* resistant to both the macrocyclic lactones and the benzimidazoles. A follow-up study conducted the following year in greater detail using additional anthelmintics (Gasbarre et al., 2009a,b) found that levamisole was efficacious in removing the drug resistant parasites. Subsequently, a drylot study (Edmonds et al., 2010) also demonstrated resistance of *C. oncophora* to injectable ivermectin and moxidectin. The recent NAHMS survey found resistance primarily to pour-on macrocyclic lactones (Gasbarre et al., unpublished data), that often resulted in a monoculture of *Cooperia* sp. in the treated cattle.

Because few studies have examined the effects of pure cultures of *Cooperia* sp. on productivity in beef cattle, the current study was designed to assess the effects of an experimental *C. punctata* infection on feed intake, growth and productivity of steer calves. Calves were infected with a recently isolated field strain of a macrocyclic lactone-resistant *C. punctata* and daily feed intake and weight gains of cattle in a feedlot setting were monitored. The study also evaluated the sensitivity of this strain of *C. punctata* to a macrocyclic lactone and a benzimidazole. The small intestines were also examined histologically to determine if there were any morphological changes that might be related to weight gain and nutrient uptake through the mucosa of infected and control animals.

2. Materials and methods

2.1. Animals

Approximately 200 steer and bull calves of unknown backgrounds were acquired from sale barns in northwestern Arkansas and northeastern Oklahoma at an average weight of 459.8 lb (208.6 kg). Upon arrival at the feedlot, at the Agri Research Center, Inc., Canyon, TX, calves were treated at the label dosage of fenbendazole (10 mg/kg) and levamisole (8 mg/kg), implanted (Ralgro®), vaccinated (Vista 5®, Calvary 9®), received metaphylactic therapy (Excede®), and intact bulls were surgically castrated. Calves were then comingled and preconditioned for approximately 1 month.

Animals were preconditioned in order to minimize health issues during the study period as well as to establish a consistent consumption pattern prior to infection. This period of time was also used to determine the parasite status of animals. Animals were fed a standard feedlot growing ration comprised of the following ingredients: steam flaked corn, chopped alfalfa hay, cottonseed culls, corn gluten feed, trace mineral supplement, molasses, fat, and micro-ingredients (e.g., feed additives and vitamins). After preconditioning, animals were revaccinated with (Vista 5®) and again treated for internal parasites in the feed (Safeguard® pellet, fenbendazole, 5 mg/kg) for two days.

The calves were then moved to pens equipped with GrowSafe® feeding nodes (Airdrie, Canada). These specialized feed bunks are designed to measure individual feed consumption in grams using individual animal electronic identification for data capture. Feed bunks were designed such that only a single animal could eat at a time, with four bunks/pen, allowing up to four animals to eat at a time in each pen. The calves were given an additional week for acclimation to the GrowSafe® system before the study was initiated.

Calves were randomly divided into two treatment groups (control and infected) each with 80 calves. Each treatment group was further divided into 2 replicated pens of 40 animals each. Assignment into each treatment group (*C. punctata* infected and control) was randomized.

At the start of the study (Day 0), inoculated/infected calves received a gavage of 1×10^5 *C. punctata* suspended in 30 mL of tap water in a dosing syringe. The syringe was subsequently rinsed twice with 30 mL of tap water each time and administered orally to the same animal. Calves assigned to the sham treatment (control group) received 90 mL of tap water orally in the same manner. Treatments were again administered in a similar manner 14 days later, with cattle in the control group receiving 90 mL of tap water and inoculated/infected cattle receiving an additional 0.825×10^5 *C. punctata* in 60 mL of tap water. The number of larvae administered attempted to duplicate infection levels observed in the field.

2.2. Parasites

The strain of *C. punctata* used for infection was one derived from a field study in Wisconsin (Gasbarre et al., 2009a,b). Eggs were initially isolated from the feces of pastured calves and then cultured for 14 days in fecal sphagnum moss cultures. Resulting larvae were inoculated into calves that had been raised since birth on concrete to preclude nematode infection. At 21 days post inoculation (PI) calves were killed and adult worms were recovered from the small intestine. Adult female *Cooperia* were handpicked and then gently ground in tap water in a hand held tissue grinder, and the resultant supernate was placed in sphagnum moss microcultures. Fourteen days after culture, larvae were harvested and inoculated in parasite-naïve calves as described previously. When calves began shedding eggs they were treated at the labeled dosage with pour-on Doramectin® and beginning 3 days later feces were collected and placed in culture for the recovery of larvae. A total of 2 such additional passages were required to build sufficient numbers of larvae for the experiment.

2.3. Procedures

Fecal samples were collected directly from the rectum from all animals on day-35, day 0 and day 56, and from 20 randomly selected animals in each treatment group biweekly from day 14 to day 49. Individual weights were recorded on arrival, allocation (day-7), the initiation of the study (day 0), at the end of the production study (day 60) and on day 74 at the end of the FECRT. Feed consumption was recorded daily from day 0 to day 74.

At the end of the 60-day production study, one pen of infected calves was treated with an injectable macrocyclic lactone (doramectin, 0.02 mg/kg) and the other infected pen was treated with a benzimidazole (fenbendazole, 5 mg/kg). Fecal egg counts on all animals in these two pens were determined on day 60 and again 14 days after treatment (day 74) to determine efficacy (Coles et al., 1992). Efficacy was calculated as: ((pre-treatment epg – post-treatment epg)/pre-treatment epg) * 100.

2.4. Fecal egg counts

The Modified Wisconsin (Bliss and Kvasnicka, 1997) technique using a 3-g sample of feces was used to determine the eggs per gram of feces (epg). The sample was washed in water, filtered through a tea strainer, resuspended in floatation medium (Sheather's sugar solution with a specific gravity of 2.0–2.5) in two tubes and a coverslip placed on the top of each tube tubes. The samples were allowed to stand for 2 h prior to the removal of the coverslips and both coverslips were removed to a microscope slide and counted. This technique had a sensitivity of <1 epg and data reported as arithmetic means.

2.5. Necropsy

Four calves were randomly selected, one from each pen, and necropsied on day-21 (3 weeks after arrival treatment) to confirm parasite free status. An additional three animals were randomly selected from each treatment group for necropsy on day 35 (to confirm infection status) and day 60 and an additional three animals from each of the two infected-treated pens on day 74 of the study. Necropsies were conducted at the West Texas A&M University Meat Laboratory (Canyon, TX). Feed was withheld from selected calves for approximately 12–18 h prior to necropsy to reduce fill in the digestive tract to facilitate worm recoveries.

Animals were euthanized humanely using a captive bolt and then exsanguinated by severing the carotid arteries and jugular veins. The intestinal tract was ligated at the esophagus and rectum in situ and removed from the abdominal cavity. Subsequently, the gastrointestinal tract (GI) was ligated into anatomic segments, including the abomasum, small intestine, large intestine and cecum. Each segment of GI tract was opened longitudinally and stripped (pulling the organ between the fingers) in tap water, and the procedure was repeated at least two times. Duplicate 10% aliquots were collected and fixed with formalin (10% final concentration). Additionally, each abomasum was soaked in tap water overnight; washed and 5% aliquots were preserved in 10% w/v formalin. Subsequently, a 10% aliquot was collected from one of the residue samples from each organ and was sieved using a 400 mesh sieve. The retained portion was examined under a 10× lens or a stereoscopic microscope and all nematodes were collected for subsequent identification and enumeration. Actual identification of the recovered nematodes was accomplished using a stereoscopic or compound microscope. Where males of more than one species were found in the sample, females and fourth stage larvae were assigned to species based on the relative proportion of the males.

2.6. Pathology

Prior to worm recovery, multiple samples from the proximal small intestine of each calf were collected and fixed in neutral-buffered formalin. The fixed samples were routinely processed and sectioned at 5 μm before being stained with either hematoxylin and eosin (H&E) or Alcian blue/periodic acid Schiff (PAS). Slides were evaluated histologically by two of the investigators, blinded to treatment groups and case identification. The study was divided into three time points, preinoculation, day 35 and day 60 for both infected and control animals. Five randomly-selected grid fields (0.13 mm^2) centered on the mid-level

of the small intestinal mucosa per animal for the following parameters were evaluated: (1) Eosinophils (Eos) and globule leukocytes (GL): total number of cells/grid field counted; (2) Intra-epithelial lymphocytes (IEL) and mononuclear cell population density (MCPD): semiquantitative grade of 0–3 with 3 representing the highest number or most dense population of cells/structures. For goblet cells (Goblet): a semiquantitative grade of 0–3 assigned to each animal (using a representative 10× field photomicrograph).

2.7. Statistical analysis

The study was conducted and summarized in two phases; animal served as the experimental unit in both phases and cattle that died or were euthanized were excluded from the growth performance data. For the first phase (day 0 to day 60), data were analyzed as a randomized complete block design and the statistical model included the fixed effect of treatment (infected or control) and the random effect of block (1 block = 2 pens). For the second phase (day 60 to day 74), treatments were arranged in a 2 × 2 factorial of infection status (infected or control) and anthelmintic administration (macrocyclic lactone or benzimidazole). These data were analyzed as a completely random design. The statistical model included the fixed effects of infection status, anthelmintic administration, and infection status × anthelmintic administration, and the random effect of block. In the event of an interaction, means were separated using Fisher's Least Significant Difference (LSD).

For histology data, independent models were evaluated for before infection, 35 days after infection, and 60 days after infection because cattle were sacrificed at each time point. For all time points for eosinophils and GL, the model included the fixed effect of treatment and animal served as the experimental unit. Means were separated by a protected LSD. Score data for IEL (0–3 by 1), MCPD (0–3 by 1), and goblet cells (0–3 by 0.5) were ranked and analyzed by the Wilcoxon test.

3. Results

3.1. Fecal egg counts

Fecal egg counts showed that no animals were shedding eggs at the time of initial infection (day 0) (Table 1). Strongyle type eggs were first detected on day 14 in *Cooperia* infected cattle. Subsequently, egg counts showed the over-dispersed distribution characteristic of gastrointestinal nematode infections with the standard deviations larger than the mean epg. The fecal egg count reduction test (Day 60 and 74) for the fenbendazole treated calves was 98.1% and 8.8% for the doramectin treated group.

3.2. Necropsy worm recovery and speciation

The only nematodes demonstrable after the initial deworming (Day-21) were a few inhibited larvae of *Ostertagia* sp. in two of the animals, with recoveries of 80 and 720 larvae. At 35 days PI (Table 2) primarily *C. punctata*, 98%,

Table 1
Fecal egg counts.

Day		0 1 October	14 15 October	21 22 October	28 29 October	35 5 November	42 12 November	49 19 November	56 30 November
Control	Mean	0.00	0.00	0.45	0.50	1.00	0.95	0.20	1.01
	StdDev	0.00	0.00	1.15	0.76	2.53	1.88	0.41	4.16
	n	80	19	20	20	20	20	20	75
Infected	Mean	0.00	62.53	167.00	81.65	142.60	87.00	79.20	55.77
	StdDev	0.00	55.77	204.79	85.18	188.94	135.03	198.27	163.03
	n	77	18	20	20	20	18	20	74

Table 2
Summary of worm recovery.

		Abomasum		Sm Int	Lg Int	Cecum
Infected	Hae	Oster	Cooperia	Cooperia	Cooperia	Oesoph
Day 35 PI						
19	900	0	0	15,600	0	0
31	0	700	0	27,100	100	0
113	200	0	0	26,400	0	0
Control						
44	0	0	0	0	0	0
96	0	0	0	0	0	0
186	0	0	0	0	100	0
Day 60 PI						
12	0	0	0	100	0	0
109	100	0	100	9,600	0	0
162	100	0	0	15,900	0	100
Control						
45	0	0	0	0	0	0
105	0	0	0	0	0	0
143	0	0	0	0	0	0

Cooperia = 98% + *Cooperia punctata*, <2% *Cooperia oncophora*.
Abbreviations: Sm Int = small intestine, Lg Int = large intestine, Hae = *Haemonchus*, Oster = *Ostertagia*, Oesoph = *Oesophagostomum*.

and 2% *C. oncophora* were recovered from the small intestine of infected cattle with a mean of 23,033 adult worms. There were also a few *Haemonchus* and *Ostertagia* recovered from the abomasum of infected animals, and a few *C. punctata* (100) were recovered from the large intestine of one control calf. The nematodes recovered at the end of phase 1 (Day 60) were primarily *C. punctata* (98%), with an average of 8,533 worms recovered from the inoculated calves. *Haemonchus* was recovered from the abomasum of one animal and *Oesophagostomum* was recovered from the cecum of one animal. No worms were recovered from control cattle on Day 60.

Worms recovered from the anthelmintic treated study (Day 74) are presented in Table 3. There was a dramatic reduction in worms recovered from the fenbendazole treated animals compared to those receiving doramectin.

3.3. Pathology

Macroscopically, the mesenteric lymph nodes of the infected animals were substantially increased in size compared to the uninfected controls. The small intestinal mucosa was thickened with an increased amount of mucus in inoculated calves. Within the intraepithelial compartment, there was a mild trend showing low to moderate numbers of intraepithelial lymphocytes and globule leukocytes between small intestinal epithelial cells and also moderate numbers of small- to medium-sized aggregates of eosinophils scattered primarily within the lower lamina propria. Quantitative analysis of eosinophils, and globule leukocytes revealed no significant differences between the infected and control groups at any of the time points. Semi-quantitative analysis of intraepithelial lymphocytes and the mononuclear cell population revealed no significant differences between the infected and control groups at any of the time points. Semi-quantitative analysis of goblet cells revealed a significant increase ($p = 0.04$) in the density of goblet cells within the intestinal epithelium of inoculated calves at day 60 compared to control calves (Table 4).

3.4. Production

The average daily gain and dry matter intake for the two groups, uninfected and infected, are presented in Table 5. Control cattle gained weight 7.4% more rapidly ($p = 0.02$) than infected animals (3.24 vs. 3.00 lb/day, (1.47 kg vs. 1.36 kg) respectively) and infected animals also consumed 1.5 lb (0.68 kg) less dry feed than control cattle ($p = 0.02$).

3.5. Anthelmintic resistance status

Using the FECRT, the efficacy of the macrocyclic lactone treated group was 8.8% while the efficacy of the benzimidazole was 98.1%. The parasite recoveries (Table 3) from the macrocyclic lactone treated group had an average of 24,733 *Cooperia* spp. Recovery of nematodes from the benzimidazole treated animals had an average of 167 *Cooperia* spp. Species identification of these parasites again showed that there were *C. punctata* and *C. oncophora*, 98% and 2%, respectively. While there was a dramatic reduction in the egg counts and worm recoveries in the two classes of anthelmintics, there were no significant differences in ADG or DMI over the 14 day period.

4. Discussion

Cooperia spp. have become the most prevalent gastrointestinal nematode parasites in cattle in the United States as reported by the 2008 USDA NAHMS, Beef Cow/Calf Survey (Stromberg et al., unpublished data). This is most likely a result of the extensive use of topical macrocyclic lactones and the development of resistance to these compounds by *Cooperia*. Such selection has led to the appearance of monocultures of *Cooperia* spp. which heretofore have not often been seen in pastured cattle. When ivermectin was first released, *C. oncophora* was the dose limiting parasite (Njue and Prichard, 2004). Nematode resistance to the avermectins/milbemycins has continued to develop, primarily to *Cooperia* spp. This was first reported in New Zealand (Pomroy, 2006), then extensively in Europe (Coles, 2004).

Table 3
Worm recovery at day 14 of the fecal egg count reduction test study.

14 days Rx		Abomasum		Sm Int
Fbz	Hae	Oster	Cooperia	Cooperia
9	0	0	0	100
38	0	0	0	400
53	0	0	0	0
Dor				
44	0	0	100	31,500
96	0	0	100	6600
186	0	0	200	35,700

Abbreviations: Hae = *Haemonchus*, Oster = *Ostertagia*, Sm Int = Small intestine, Fbz = fenbendazole, Dor = doramectin.

Table 4
Effect of infection with *Cooperia punctata* on proximal small intestine histology parameters.

Item	Control	Infected	SE	*P*-value
Day 0 (before infection)				
n	2	2	–	–
Eosinophils [mean cells/grid]	28	30	19	0.96
Globule leukocytes [mean cells/grid]	2.2	3.6	2.6	0.74
Intraepithelial lymphocytes sum score	6	4	–	0.64
MCPD* [sum score]	5	5	–	0.99
Goblet cells [sum score]	7	4	–	0.47
Day 35				
n	3	3	–	–
Eosinophils [mean cells/grid]	70	81	26	0.79
Globule leukocytes [mean cells/grid]	0.6	0.8	0.3	0.69
Intraepithelial lymphocytes sum score	13	8	–	0.20
MCPD* [sum score]	11	10	–	0.82
Goblet cells [sum score]	9	12	–	0.48
Day 60				
n	3	3	–	–
Eosinophils [mean cells/grid]	42	79	14.6	0.23
Globule leukocytes [mean cells/grid]	1.2	0.1	0.5	0.23
Intraepithelial lymphocytes sum score	7	14	–	0.11
MCPD* [sum score]	8	14	–	0.11
Goblet cells [sum score]	6	15	–	0.04

* MCPD = mononuclear cell population density.

The NAHMS Beef Cow/Calf survey also noted the apparent resistance of *Cooperia* spp. to the topical macrocyclic lactones (Gasbarre et al., unpublished data). This invariably leads to the question; does this parasite have an impact on cattle growth and productivity?

It is generally accepted that parasites have a negative effect on cattle growth and productivity. This is supported by a Georgia study (Stuedemann et al., 1989) where a 0.04 kg ADG was observed for the parasite free calves when compared to control calves. They also observed an improvement in the pregnancy rate of parasite-free cows compared to the infected control cows (98% vs. 75%). Similarly, dairy replacement heifers grow better when they are parasite free. Elsener et al. (2001) reported an increased weight gain of 16 kg over a 143 day period when parasite-free heifers were compared to parasitized controls. Increased milk production was also observed in parasite free milk cows when compared to those that were parasitized (Gross et al., 1999). Most of these studies were evaluated by removing parasites from a population and making one group parasite free with an anthelmintic. There have been few studies where productivity was evaluated with a single species infection.

Table 5
Effect of infection with macrocyclic lactone resistant *Cooperia punctata* on performance reported in pounds.

Treatment	Pen	Average Wt. Day 0	Average Wt. Day 60	Average daily gain (ADG)	Avg. consumption
Uninfected	1	616.2	801.4	3.22	27.9
	3	626.0	818.9	3.26	27.5
	Avg.	621.1	810.2	3.24	27.7
Infected	2	621.3	792.5	2.92	26.3
	4	619.7	802.0	3.07	26.3
	Avg.	620.5	797.3	3.00	26.3
Difference		0.6	12.9	0.24*	1.5*
Percent difference				7.4%	5.4%

* Significant at $p = 0.02$.

The current study used a macrocyclic lactone-resistant strain of *C. punctata* isolated from cattle in a research study in Wisconsin (Gasbarre et al., 2009a). The goal was to provide a monoculture infection that would be similar in composition and magnitude to that seen under natural field conditions as observed in the Wisconsin study (Gasbarre et al., 2009a,b). Egg counts in the current study ranged from 0 to over 1000 epg. Table 1 shows that the average fecal egg counts are similar to those reported in the literature for naturally infected animals (Gasbarre et al., 2009b). The large standard deviation shows the over dispersed distribution characteristic of a previous exposure and the expression of varying degrees of immunity to gastrointestinal nematodes (Crofton, 1971a,b). Similarly, Table 2 shows the average number of worms recovered from randomly selected animals at necropsy, with an average of 23,000 worms at 35 days PI dropping to 8500, 60 days after inoculation. These results are similar to parasite levels that are observed in naturally infected cattle in the United States (Gasbarre et al., 2009b). The recovery of a few other species (*C. oncophora, Haemonchus* sp. and *Ostertagia ostertagi*) may have been due to contamination of the infection inoculum or fence line infection.

The egg counts became positive at 14 days PI and calves continued shedding throughout the study to day 60. This is similar to the prepatent period previously described as 11–16 days (Bailey, 1949; Leland, 1995). All these data suggest a successful infection, simulating a natural field infection.

A question raised quite frequently is; does *C. punctata* have any significance in cattle production today compared to that reported about 45 years ago (Herlich, 1965). This is even more important when *C. punctata* is present in increasing numbers and often as a single species (monoculture) infection (Gasbarre et al., unpublished data). This study attempted to answer this question by comparing weight gain and feed consumption of infected and control animals over a 60 day trial period as well as the histological characterization of the proximal small intestine. All calves (except for 1) in the inoculated group were infected as indicated by a positive fecal egg count on one or more sample days (the calf with 0 egg counts was included in data analysis).

The GrowSafe® System provided a unique opportunity to measure individual animal feed intake on a daily (continuous) basis. Daily consumption (Dry Matter Intake, DMI) and weight gains over the experimental period allows the calculation of DMI and Average Daily Gain (ADG). Both ADG and DMI were each significantly ($p = 0.02$) impacted by an infection with a monoculture of *C. punctata*. In this study, a decrease of 0.24 lb (0.11 kg) of ADG was observed for the infected calves, a 7.4% decrease. Dry matter intake was also decreased by 1.5 lb (0.68 kg), a 5.4% impact with a *C. punctata* infection. These data confirm that *C. punctata* has an economically important effect on appetite and nutrient uptake and/or utilization.

A similar, but smaller study (involving ten calves) found that the difference in ADG between *C. punctata* infected and uninfected calves was 0.48 lb (Alicata and Lynd, 1961). Infections with other species of *Cooperia* have also shown an impact on growth and productivity, although these differences were often not quantified. Infection with *C. pectinata* resulted in a 28 lb gain advantage to the uninfected control animals over a four-week experimental period (Keith, 1967). A similar study by Herlich (1965) found that *C. pectinata* was as pathogenic as *C. punctata* and that *C. oncophora* appeared to have less impact on both clinical signs and productivity. However, a study by Armour et al. (1987) found that an experimental infection with *C. oncophora* was responsible for inappetence and a reduced gain that was about half of that observed in the uninfected controls.

Previous studies with experimental infections with *Cooperia* spp. also observed an effect on clinical signs, such as fecal consistency (stool softening to diarrhea), inappetence resulting in lowered feed consumption, and loss of plasma proteins. Experimental infections with *Cooperia* spp. resulted in gross lesions in the upper portion of the small intestine, most often the duodenum. These included a catarrhal enteritis and thickening of the gut (Bailey, 1949). Similar findings were reported 55 years later, finding the majority of the worms in the first segment of the small intestine (Rodrigues et al., 2004). Histologically they observed an increase in eosinophils and neutrophils between days 21 and 35 (end of the study). The current study found a significant increase in the density of goblet cells within the epithelium of the proximal small intestine, but no increase in the eosinophils, intraepithelial lymphocytes, globule leukocytes or mononuclear cell population.

The sensitivity of *C. punctata* to anthelmintics used in this study was confirmed as resistant to a macrocyclic lactone (doramectin) and sensitive to the benzimidazole (fenbendazole).

This study conclusively demonstrates that *C. punctata* is an important parasite in cattle, and that successful parasite control programs must necessarily control this parasite. However the actual contribution of *Cooperia* spp. to overall production losses of mixed infections may not be so evident. Removal of potentially competitive species may allow the pathogenic potential to increase. Given the increased resistance of this parasite to the macrocyclic lactones and the potential differences in optimal transmission periods for this parasites, it is important that: (1) producers and veterinarians monitor the effectiveness of treatments, and (2) the timing of strategic nematode control programs be reconsidered and adapted to address the actual parasite fauna at a given location.

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