PEER REVIEWED

Evaluation of Efficacy and Benefit of Ivermectin with Clorsulon and Long-acting Moxidectin in Replacement Beef Heifers

J.G. Powell[1], *DVM, PhD;* **T.A. Yazwinski**[1], *PhD;* **C.A. Tucker**[1], *PhD;* **Z.B. Johnson**[1], *PhD;*
A.H. Brown, Jr.[1], *PhD;* **J.L. Reynolds**[1], *MS;* **B.C. Clymer**[2], *PhD*
[1]*Department of Animal Science, University of Arkansas, Fayetteville, AR 72701*
[2]*11395 South Western Street, Amarillo, TX 79118*
Corresponding author: J.G. Powell, Email: jerpow@uark.edu

Abstract

A two-year study was conducted to assess the effects of ivermectin (with clorsulon) and long-acting moxidectin on the development of replacement beef heifers carrying naturally occurring parasite infections. Replacement beef heifers (n = 105) were obtained at weaning and co-grazed on permanent pastures throughout the 686-day study. Study heifers were treated with ivermectin and clorsulon (IVCL), long-acting moxidectin (LMXD), or left untreated (CON). Treatments were administered on days 0 and 149. Compared to CON, heifer body weights were greater ($P < 0.05$) for LMXD and IVCL-treated animals on days 175, 238, 287, 369, and 433. Average daily gains were greater ($P < 0.01$) for LMXD and IVCL-treated heifers compared to CON heifers from days 0 to 433. Fecal strongyle egg counts were lower ($P < 0.01$) for LMXD-treated heifers on days 14, 64, 149, 169, 238, and 287 compared to the IVCL and CON groups. Fecal egg counts for the IVCL group were lower ($P < 0.01$) than those in the CON group on days 14 and 169, the samplings subsequent to animal treatments. Weight gain of calves born to the study heifers was greatest for calves born to LMXD-treated heifers, intermediate for calves born to IVCL-treated heifers, and lowest for calves born to CON heifers.

Keywords: heifers, ivermectin, moxidectin, parasites

Résumé

Une étude de deux ans a évalué l'effet de l'ivermectine (additionnée de clorsulone) et de la moxidectine à action prolongée sur la croissance de génisses de bovins de boucherie de remplacement infestées naturellement par des parasites. Ces génisses de remplacement (n = 105) ont été obtenues au sevrage et regroupées en pâturage permanent pendant les 686 jours qu'a duré l'étude. Selon l'un de nos trois groupes de traitements, les génisses ont été soignées à l'ivermectine additionnée de clorsulone (IVCL), à la moxidectine à action prolongée (LMXD) ou non traitées (CON). Les traitements ont été administrés aux jours 0 et 149.

Par rapport aux témoins, le poids vif des génisses s'est montré plus élevé ($P < 0,05$) dans les groupes LMXD et IVCL aux jours 175, 238, 287, 369 et 433. Les génisses traitées à la LMXD et à l'IVCL ont affiché un gain moyen quotidien supérieur ($P < 0,01$) à celui des génisses témoins, entre les jours 0 et 433.

D'autre part, on a compté moins d'œufs de strongyles ($P < 0,01$) dans les fèces des génisses traitées à la LMXD que dans celles des génisses traitées à l'IVCL ou des génisses témoins, aux jours 14, 64, 149, 169, 238 et 287. Les œufs étaient moins nombreux ($P < 0,01$) dans les fèces des génisses traitées à l'IVCL que dans celles des génisses témoins, aux jours 14 et 169, soit dans des échantillons prélevés à la suite des deux jours de traitement.

Quant au gain de poids des veaux provenant des génisses de l'étude, il fut le plus élevé chez les veaux nés des génisses traitées à la LMXD, intermédiaire chez les veaux des génisses traitées à l'IVCL et le moins élevé chez ceux des génisses témoins.

Introduction

Development of replacement heifers is a major economic endeavor in the beef cattle industry. Parasitism of cattle by gastrointestinal nematodes can be significantly detrimental to growth and performance of grazing animals.[19] Intestinal parasitism can negatively impact average daily gain (ADG) and reproductive development in beef heifers.[22] Anthelmintic treatment administered to replacement heifers has been associated with early onset of puberty,[6,9] potentially increasing reproductive longevity. Additionally, beef heifers treated for nema-

tode infections have been shown to wean heavier calves compared to untreated controls.[7]

Macrocyclic lactones are the most widely used class of anthelmintics today.[15] This class of drug includes the cattle endectocides abamectin, ivermectin, doramectin, eprinomectin, and moxidectin. Primary targets of these chemicals are the glutamate and gamma-amino-butyric acid gated ion channels of nerve and muscle cells, leading to flaccid paralysis of targeted parasites.[16]

A new formulation of long-acting moxidectin has been developed, but is not currently commercially available in the US. Recent US and international studies have shown long-acting moxidectin to be effective for extended control of parasite burdens.[2,4,20] Compared to using a conventional formulation of macrocyclic lactone, administration of long-acting moxidectin has been shown to confer longer post-treatment parasite control.[4,21] The purpose of this study was to compare injectable formulations of long-acting moxidectin and ivermectin plus clorsulon for efficacy of parasite control and benefits regarding growth, reproductive performance, and offspring growth performance in beef replacement heifers over a 686-day period.

Materials and Methods

In total, 131 beef replacement heifers of predominantly Angus breeding were utilized in the study. All heifers were born between September 03 and December 27, 2005, and originated from two different sources in northern Arkansas. Study heifers were weaned and delivered to the Savoy Station of the University of Arkansas Beef Cattle Research Center on May 15, 2006. Following arrival, all animals were provided a 30-day acclimation period. During this time, body weight (BW) and strongyle fecal egg counts (FEC) were obtained. Cattle were housed as one group on permanent pastures during the acclimation period. In total, 105 heifers were ultimately selected for the study based on the BW, FEC, and acceptable animal disposition. Based on animal condition and nematode egg counts (day -30 geometric mean eggs per gram (EPG) of feces = 57.3 ± 5.7; min. – max. = 0 - 423), study animals were considered naturally parasitized at relatively low levels immediately prior to the study.

Permanent pastures were used for co-grazing the animals throughout the study. Pastures provided a mixture of perennial warm season and cool season forages. Bermuda grass (*Cynodon dactylon*) and endophyte-infected tall fescue (*Lolium arundinaceum*) were the predominant forages available.

Throughout the study, all animals were maintained and cared for in compliance with the University of Arkansas Animal Care and Use Committee Protocol #06052. Shortly after arrival at the experiment station, each study animal was identified with uniquely numbered ear tags and given two rounds of vaccinations[a,b,c] as well as a metaphylactic antibiotic injection.[d]

Prior to animal allocations to treatment group, all heifers were tested for persistent infection by the bovine viral diarrhea virus (PI-BVDV) via an ear-notch tissue biopsy using the antigen-capture ELISA test.[e] One animal was PI with BVDV, and therefore was immediately removed from the group and the premises.

Study animals were commingled and managed as one group on permanent pastures for the entire study, with the exception of subgroup pasturing during breeding periods. Even during breeding periods, however, equal numbers of animals from each treatment group were grazed together. All study animals were given *ad libitum* access to pasture forage, water, and mineral supplement. A stocking rate of approximately one heifer per 0.83 ha was maintained throughout the study. A soy-hull supplement was fed daily at the rate of 1% of animal BW from day 30 through day 287, and then on an as-needed basis at the above rate when forage availability was deemed low.

Heifers were ranked by their day -2 strongyle FEC and grouped into five blocks containing 21 animals per block. Within each block, heifers were then ranked by day -1 BW and starting at the top, bracketed by threes into replicates. Each of the three heifers within each replicate was then randomly assigned to one of three treatment groups.

The initial three treatment groups were: (1) long-acting moxidectin[f] (LMXD); (2) ivermectin plus clorsulon[g] (IVCL); and (3) an untreated control (CON). Treatments were administered on day 0 (animals were approximately eight months of age) and again on day 149. LMXD was a 10% non-aqueous solution administered subcutaneously into the left ear with a 1-inch (2.54 cm), 18-gauge, B-bevel needle at the volumetric rate of 1 mL/220 lb (100 kg) BW, delivering moxidectin at the rate of 0.45 mg/lb (1.0 mg/kg) BW. IVCL was administered subcutaneously into the left side of the neck with a 0.75-inch (1.9 cm), 16-gauge needle at the volumetric rate of 1 mL/110 lb (50 kg) BW (0.091 and 0.91 mg/lb; 0.2 and 2.0 mg/kg BW for ivermectin and clorsulon, respectively). Control animals received no placebo injections, but were subject to the same handling and management as the treated animals.

A second set of treatment groups were established at parturition. Half of the study animals from each of the treatment groups (LMXD, IVCL, and CON) received moxidectin[h] topically (MXPO) at a dose of 227 mcg/lb (500 mcg/kg) BW, and the other half of the animals from each group were left untreated. These subsequent treatments were assigned in chronological order and for animals in each of the initial treatment groups (poured, control, poured, control, etc.) and administered within seven days of calving.

The initial portion of the study (time of weaning of the study heifers up through exposure to bulls) was conducted to compare the short-term benefits of long-acting moxidectin and ivermectin to untreated controls relative to the growth, development, and reproductive status of replacement beef heifers. The subsequent treatments at calving were given to assess the benefits of treatment at calving, a consistent recommendation by University of Arkansas parasitologists. Therefore, each of the initial treatment groups were split equally, so that half of each initial treatment group was dewormed with pour-on moxidectin once at calving and the other half was not.

During the first year breeding period (day 175 to day 259), heifers from each treatment group were randomly split into four separate breeding groups (three groups of 26 animals, and one group of 27 animals). Each group was initially placed on one of four breeding pastures, with each pasture containing one fertile bull. After 21 days of exposure, each group was rotated from their assigned pasture to one of the other breeding pastures. This rotation was repeated three times in order to equally expose each breeding group to all four breeding pastures and bulls.

After calving, rebreeding took place during the second year breeding period (days 548 to 615). Only three separate breeding groups were required, due to the culling of seven open heifers after the first breeding period. Of the three second year breeding groups, two groups contained 33 animals and one group contained 32 animals. These second year breeding groups were rotated every 21 days between three breeding pastures and fertile bulls. Approximately 30 days after the conclusion of each breeding season, the heifers were evaluated for pregnancy via transrectal ultrasonography.

Fecal strongyle egg counts, with coproculture, and/or animal BW were obtained on days 0, 14, 64, 149, 169, 238, 259, 287, 369, 433, 546, 615, 658, and 686. All FEC were performed using 1 gm of feces and a magnesium sulfate flotation-centrifugation technique.[1,17,18] Coprocultures were performed on all fecal samples with strongyle egg counts greater than 10 eggs per gram, and when sufficient feces was obtained for a successful culture (30 grams as a minimum). For each coproculture, feces were mixed with ground corn cobs and incubated at room temperature for 10-14 days. Infective larvae harvested from each culture (all or the first 100) were identified to genus based on morphology.[5]

At birth, each calf born to a study heifer was identified with a numbered ear tag that corresponded with the dam. Calves were also weighed within 24 hours of birth, and bull calves were castrated using an elastrator band. Calves received no anthelmintic treatment prior to weaning. On day 615, when the calves were approximately four months of age, each calf was administered routine vaccinations consisting of an inactivated four-way respiratory vaccine[i] and a clostridial bacterin-toxoid.[j]

At weaning (day 686), calf BW were recorded and adjusted according to the Beef Improvement Federation Guidelines.[13] The formula used for the adjusted weaning weight (AWW) was: AWW = [(actual weaning weight - actual birth weight) / (weaning age in days)] x 205 + (actual birth weight + standard adjustment for age of dam and calf gender).

Statistical analyses for FEC, BW, ADG, and coproculture percentages were conducted using PROC GLM of SAS,[12] with significant differences assigned at $P < 0.05$. The egg counts were transformed using natural log [Y = $\log_{10}$ (x + 1)] prior to analysis of variance. Geometric means for the egg counts were then generated for presentation in this manuscript. All means were separated using the PDIFF option of GLM. Analysis of pregnancy data was performed using PROC FREQ of SAS. The chi-square statistic was utilized to determine independence of homogeneity between treatments.

Results

Throughout the entire study, the vast majority of FEC were relatively low, indicating a low level of parasitism. Geometric means of strongyle FEC by treatment group and study day are presented in Table 1. All initial treatment groups had similar counts on day 0. Following initial treatments, very low counts were maintained in LMXD-treated heifers for the remainder of the study. Strongyle egg counts for LMXD-treated heifers were lower ($P < 0.01$) on days 14, 64, 149, 169, 238, and 287 compared to counts for animals of the IVCL and CON groups. Counts for the IVCL group animals were lower ($P < 0.01$) compared to the CON group only on days 14 and 169 (14 and 20 days immediately following treatments); otherwise, FEC for the IVCL-treated heifers were similar to CON heifers. From day 369 (220 days following the last treatment) until the end of the study, FEC were similar for all treatment groups. Strongyle FEC data seen at calving and beyond are summarized in Table 2.

Coproculture larval counts (Table 3) revealed that all treatment groups exhibited similar per-genera larval percentages of L_3 strongyle larvae on day 0. LMXD-treated heifers had FEC that were too low to permit coproculture on days 14 and 169. On days 14 and 64, IVCL-treated animals had higher ($P < 0.05$) percentages of L_3 as *Cooperia*, and lower percentages of L_3 as *Ostertagia* and *Trichostrongylus* compared to CON animals. LMXD-treated heifers had higher ($P < 0.05$) percentages of L_3 as *Cooperia*, but lower ($P < 0.05$) percentages of L_3 as *Ostertagia* compared to IVCL and CON groups on days 64 and 149. LMXD-treated heifers exhibited higher

($P < 0.05$) percentages of L_3 as *Cooperia* on days 238 and 287 compared to IVCL and CON animals. On day 369, no differences were identified for L_3 percentages among treatment groups for any strongyle genus. At 20 days subsequent to the repeat of the initial treatments (day 169), percentages of L_3 as *Cooperia* in the IVCL-treated heifers were much lower than percentages seen following initial treatment. Also on day 169, IVCL-treated heifers exhibited a much higher percentage of L_3 as *Haemonchus* compared to coprological samples taken subsequent to the initial treatment. Percentages of L_3 as *O. radiatum* were similar among all treatment groups on days 0, 238, 287, and 369. Percentages of L_3 as *O. radiatum* were higher ($P < 0.05$) in the CON heifers compared to the

Table 1. Strongyle eggs per gram (EPG) of feces, geometric mean (GM) and range by initial treatment group and study day (days 0 to 433).

		Study day								
Treatment group		Day 0 (Initial treatment)	Day 14	Day 64	Day 149 (Repeated treatment)	Day 169	Day 238	Day 287	Day 369	Day 433
LMXD[d]	GM	31.2[a]	1.4[c]	7.4[b]	16.6[b]	1.2[c]	3.0[b]	2.3[b]	3.5[a]	22.2[a]
	Range	1 - 599	0 - 18	0 - 131	0 - 220	0 - 3	0 - 88	0 - 72	0 - 25	1 - 183
IVCL[e]	GM	35.5[a]	8.7[b]	73.9[a]	68.1[a]	9.3[b]	12.1[a]	6.7[a]	6.5[a]	22.8[a]
	Range	2 - 258	0 - 171	2 - 402	2 - 468	0 - 120	0 - 129	0 - 68	0 - 91	0 - 178
CON[f]	GM	35.0[a]	65.7[a]	115.8[a]	56.5[a]	21.6[a]	10.2[a]	5.3[a]	5.2[a]	17.0[a]
	Range	2 - 281	2 - 770	0 - 800	1 - 469	0 - 403	0 - 325	0 - 367	0 - 196	0 - 534

[a,b,c] Means on the same day with unlike superscripts are significantly different ($P < 0.01$).
[d]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[e]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[f]CON is control – heifers were not treated for parasites.

Table 2. Strongyle eggs per gram (EPG) of feces, geometric means (GM) by initial treatment and treatment group at calving.

Initial treatment	Treatment at calving		Point in time[e]	
			Post-calving	Day 546
LMXD[a]	MXPO[d]	GM	22.6	10.0
		Range	3 - 126	0 - 73
	CON	GM	26.1	22.3
		Range	3 - 185	2 - 139
IVCL[b]	MXPO	GM	21.0	6.4
		Range	0 - 172	0 - 131
	CON	GM	20.1	8.5
		Range	2 - 107	1 - 62
CON[c]	MXPO	GM	16.8	3.7
		Range	0 - 108	0 - 28
	CON	GM	29.5	6.0
		Range	5 - 409	0 - 111

[a]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[b]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[c]CON is control – heifers were not treated for parasites.
[d]MXPO is moxidectin pour-on (Cydectin® Pour-on, Fort Dodge Animal Health, Overland Park, KS).
[e]No significant differences were noted.

IVCL-treated heifers on days 64 and 169; percentages of L_3 as *O. radiatum* in CON heifers were similar to IVCL-treated heifers on day 433. Percentages of L_3 as *O. radiatum* were higher ($P < 0.05$) in the CON heifers compared to the LMXD-heifers on days 64 and 433.

Average initial BW was 530 ± 52.8 lb (241 ± 23.9 kg) on day 0, which was similar among all treatment groups. By day 149, LMXD-treated heifers had a higher mean BW ($P < 0.05$) compared to the CON group heifers (Table 4). Mean BW was greater ($P < 0.05$) for LMXD and IVCL-treated heifers on days 175, 238, 287, 369, and 433 compared to the CON group. As shown in Figure 1, ADG was greater ($P < 0.01$) for LMXD and IVCL heifers compared to CON heifers for study days 0

Table 3. Mean percentages of coproculture larvae by strongyle genus, initial treatment group, and study day (days 0 to 433).

		Study day								
Larvae genus	Treatment group	0	14	64	149	169	238	287	369	433
Cooperia	LMXD[d]	62.2	*	97.4[a]	84.2[a]	*	94.8[a]	100[a]	73.3	28.8
	IVCL[e]	53.4	93.1[a]	74.6[b]	30.5[b]	43.9[b]	30.7[b]	19.8[b]	33.6	13.1
	CON[f]	58.5	76.6[b]	45.9[c]	42.0[b]	24.2[b]	30.7[b]	41.6[b]	22.6	11.0
Ostertagia	LMXD	22.8	*	1.4[c]	1.0[a]	*	2.8	0	1.3	5.4
	IVCL	29.8	1.9[b]	2.7[b]	10.8[b]	0.5[b]	30.6	16.9	10.2	12.7
	CON	22.4	10.2[a]	6.6[a]	13.1[b]	9.4[a]	18.4	5	8.3	10.4
Haemonchus	LMXD	12.2	*	1.2[b]	14.8[a]	*	2.4	0[b]	16.7	56.9
	IVCL	8.0	4.8	22.6[b]	53.5[b]	55.4[b]	35.6	57.8[a]	45.5	51.5
	CON	10.3	8.4	44[c]	36.9[b]	56.6[b]	38.9	46.6[a]	51.1	52.8
Trichostrongylus	LMXD	2.2	*	0[b]	0[b]	*	0	0	7.3	3.7[b]
	IVCL	7.5	0.1[b]	0.1[b]	0.6[b]	0.2[b]	0.9	0.7	2.5	4.6[b]
	CON	7.3	3.4[a]	1.8[a]	3.4[a]	1.6[a]	5.8	2.4	4.3	8.2[a]
O. radiatum	LMXD	0.6	*	0[b]	0	*	0	0	1.3	5.1[b]
	IVCL	1.29	0.1	0[b]	4.6[a]	0[b]	2.1	4.8	8.2	18.1[a]
	CON	1.5	1.4	1.7[a]	4.6[a]	8.1[a]	6.1	5.4	13.7	17.5[a]

[a,b,c]Means of like genus and in the same column with different superscripts are significantly different ($P < 0.05$).
[d]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[e]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[f]CON is control – heifers were not treated for parasites.
*Indicates that fecal egg count was too low to conduct coproculture.

Table 4. Mean heifer body weights (lb) by initial treatment group and study day (days 0 to 433).

	Study day								
Treatment group	0 (TRT)	14	64	149 (TRT)	175	238	287	369	433 (Pre-calving)
LMXD[c]	526.7	577.1	659.8	738.3[a]	775.7[a]	872.7[a]	874.5[a]	1004.5[a]	1045.7[a]
IVCL[d]	532.2	579.3	666.4	731.7[ab]	771.5[a]	865.5[a]	867.5[a]	987.4[a]	1032.9[a]
CON[e]	532.0	578.2	654.1	705.8[b]	740.7[b]	833.4[b]	835.1[b]	954.1[b]	999.7[b]

[a,b]Means on the same day with unlike superscripts are significantly different ($P < 0.05$).
[c]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[d]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[e]CON is control – heifers were not treated for parasites.

through 433. Heifer BW immediately post-calving and thereafter are summarized in Table 5. Average treatment group BW were similar immediately post-calving, and remained similar throughout the remainder of the study.

On day 238, each study heifer was examined for pregnancy after 63 days of exposure to bulls. At this time, pregnancy rates were estimated to be 82.4, 80, and 69% for the LMXD, IVCL, and CON group animals, respectively. There were no significant differences (P = 0.32) between treatment groups. At the conclusion of the breeding season (after 84 days of exposure to a fertile bull), each heifer was re-evaluated for pregnancy. At this later time, 93% of all study heifers were pregnant, with no differences in pregnancy rate between treatment groups (91.4, 94.3, and 94.3% conceived in the LMXD, IVCL, and CON groups, respectively). The seven heifers identified as open after the first breeding period were culled from the study on day 287, leaving 98 animals for the remainder of the study.

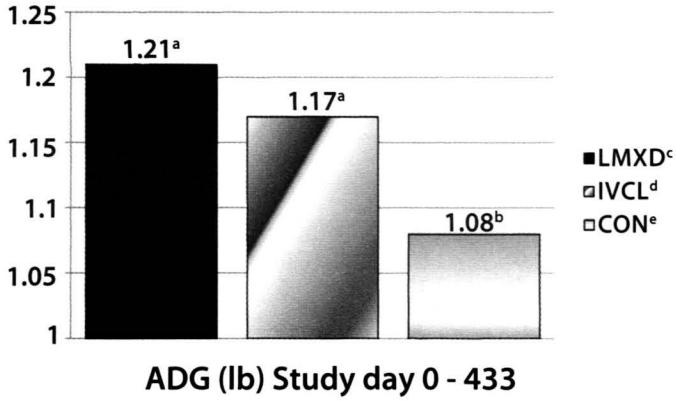

Figure 1. Mean average daily gain (lb) for heifers by initial treatment group for days 0 - 433.
[a,b]Means with unlike superscripts are significantly different ($P < 0.01$).
[c]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[d]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[e]CON is control – heifers were not treated for parasites.

At calving, FEC were similar between heifers treated at the time of calving with MXPO and untreated controls. FEC remained similar between groups on day 546 (Table 2). Coproculture larval percentages (Table 6) were similar for the treatment groups for samples collected at calving. However, for samples collected on day 546, differences between MXPO-treated heifers compared with control heifers were apparent. MXPO-treated heifers had higher ($P < 0.05$) percentages of L_3 as *Cooperia* and lower percentages of L_3 as *Haemonchus* and *Trichostrongylus* compared to control heifers. Percentages of L_3 as *O. radiatum* and *Ostertagia* were similar among MXPO-treated heifers and control heifers.

Following calving and subsequent to the rebreeding period, each cow was evaluated for pregnancy status on day 658. At that time, 98% of the heifers were pregnant, with only two of the 98 heifers identified as open. No differences for pregnancy rate were identified between initial treatment groups (LMXD/IVCL/CON) or between the MXPO/control treatment groups that were established at calving.

Calf performance was significantly affected by initial study heifer treatments (LMXD/IVCL/CON), but no statistically significant improvement resulted

Table 5. Mean animal body weights (lb) of heifers by initial treatment group from study days 546 - 686 (from post-calving until calves were weaned).[a]

Initial treatment	Treatment at calving	Study day				
		Post-calving	546	615	658	686
LMXD[b]	MXPO[e]	991.1	990.0	979.4	933.2	962.5
	CON	987.6	993.3	980.1	928.8	960.1
IVCL[c]	MXPO	979.0	1012.7	1001.0	962.9	986.9
	CON	964.9	993.1	995.5	949.3	984.3
CON[d]	MXPO	968.4	982.1	991.8	957.2	989.8
	CON	969.3	989.3	1010.7	967.6	1004.5

[a]No significant differences were noted.
[b]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[c]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[d]CON is control – heifers were not treated for parasites.
[e]MXPO is moxidectin pour-on (Cydectin® Pour-on, Fort Dodge Animal Health, Overland Park, KS).

from treating heifers with MXPO at calving. Calf birth weights were similar among all treatment groups (Table 7). However, initial treatment of study heifers with LMXD resulted in significantly heavier ($P < 0.05$) AWW and higher ADG for calves compared to those from untreated CON heifers. Additionally, AWW and ADG were similar among calves in the IVCL and CON groups. However, AWW and ADG for calves from heifers treated with LMXD were not significantly different from calves weaned from IVCL-treated heifers (Table 7). Calves weaned from LMXD heifers weighed 42.7 lb (19.4 kg) more at weaning compared to calves weaned from CON heifers, while calves weaned from IVCL-treated heifers weighed 28.9 lb (13.1 kg) more at weaning compared to calves weaned from CON heifers.

Discussion

These data indicate that within the context of this study, LMXD and IVCL provided safe and effective control against naturally-acquired strongyle nematode infections of replacement beef heifers. Based on FEC reductions, LMXD was significantly more effective than IVCL in the immediate, as well as long-term reduction of parasites. The difference in efficacy, however, was not reflected in the performance of heifers from the two

Table 6. Mean percentages of coproculture larvae by strongyle genus and treatment group at calving and beyond.

		Point in time	
Larvae genus	Treatment at calving	Post-calving (%)	Day 546 (%)
Cooperia	MXPO[c]	10.9	40.6[b]
	CON[d]	8.0	7.5[a]
Ostertagia	MXPO	28.4	18.8
	CON	28.7	19.6
Haemonchus	MXPO	44.7	36.1[a]
	CON	47.1	62.7[b]
Trichostrongylus	MXPO	4.0	1.3[a]
	CON	6.5	3.6[b]
O. radiatum	MXPO	12.0	3.1
	CON	9.7	6.5

[a,b]Means of like genus and in the same column with different superscripts are significantly different ($P < 0.05$).
[c]MXPO is moxidectin pour-on (Cydectin® Pour-on, Fort Dodge Animal Health, Overland Park, KS).
[d]CON is control – heifers were not treated for parasites.

Table 7. Mean calf birth weight, average daily gain (ADG), and adjusted weaning weight by initial treatment group.

	Initial heifer treatment group			
	LMXD[c]	IVCL[d]	CON[e]	*P*-value (Pr > F)
Birth weight (lb)	66.2	65.1	61.4	0.36
ADG to weaning (lb/day)	1.98[a]	1.91[a,b]	1.80[b]	0.017
Adjusted[f] weaning weight (lb)	480.9[a]	467.1[a,b]	438.2[b]	0.016

[a,b]Means in the same row with different superscripts are significantly different ($P < 0.05$).
[c]LMXD is long-acting moxidectin (Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS).
[d]IVCL is ivermectin plus clorsulon (Ivomec® Plus Injectable, Merial, Duluth, GA).
[e]CON is control – heifers were not treated for parasites.
[f][(actual weaning weight - actual birth weight) / (weaning age in days)] x 205 + (actual birth weight + standard adjustment for age of dam and calf gender)

treated groups, an observation which may be due to the mild nature of the parasitism encountered in this study, as well as co-grazing of heifers from the various treatment groups. At the end of the first 433 days of this study, heifers treated with LMXD exhibited a 46 lb (20.9 kg) improvement in weight gain compared to CON while heifers treated with IVCL exhibited a 33.2 lb (15.1 kg) improvement compared to CON. Similar results have been reported elsewhere wherein significantly greater weight gains in anthelmintically-treated heifers occur when compared to untreated controls.[3,11]

LMXD heifers exhibited greater FEC reductions compared to IVCL-treated heifers throughout the initial portion of the study. Fourteen days subsequent to the initial treatments, LMXD-treated heifers exhibited a 95% FEC reduction while IVCL-treated heifers exhibited only a 75% FEC reduction. Furthermore, LMXD continued to provide greater than 90% FEC reductions for up to 64 days post-treatment. Findings reported from other studies indicated similar durations of post-treatment FEC reductions in stocker calves treated with LMXD.[2,21]

Results from coprocultures showed that MXPO-treated animals exhibited higher percentages of *Cooperia* and lower percentages of *Haemonchus* and *Trichostrongylus* compared to untreated animals. Similarly, pre-calving coproculture larval counts (Table 3) revealed that following treatment, LMXD-treated heifers had higher ($P < 0.05$) percentages of L_3 as *Cooperia* compared to IVCL and CON groups on days 64 and 149. Results from similar studies have also indicated that moxidectin, as well as the other macrocyclic lactones, are least effective against *Cooperia* as compared to the other strongyle genera.[4,20]

Reports differ on the effect of anthelmintic treatment on cycling cattle and respective pregnancy rates. Some studies have indicated that treatment with an anthelmintic provides significant improvement in pregnancy rates.[7,14] Other studies have reported no differences in pregnancy rates due to anthelmintic treatment.[9,10,22] Results from the current study indicate that treatment with LMXD or IVCL has no effect on pregnancy rate after an 84-day breeding period compared to untreated controls. This may be explained by the relatively low parasite burdens encountered throughout the study, as well as the good body condition of all animals at trial onset and thereafter.

Calf performance was superior for calves weaned from study heifers treated with LMXD, intermediate for calves weaned from heifers treated with IVCL, and least for calves from CON heifers. Calves weaned from LMXD heifers exhibited significant benefits in AWW and ADG compared to calves weaned from CON heifers, while calves weaned from IVCL heifers were not significantly different for AWW and ADG compared to calves weaned from CON heifers.

The above results may be explained by research conducted by Ploeger *et al* on gastrointestinal nematode infections in replacement dairy heifers.[8] They demonstrated that parasite-induced BW reductions of heifers resulted in lowered milk production during the first lactation. LMXD and IVCL-treated heifers exhibited a 46 and 33.2 lb advantage ($P < 0.05$) in BW when compared to untreated controls on day 433 (five days ahead of the calving). Heifers in the current study that exhibited higher pre-calving BW could have produced more milk during their subsequent lactation period, consequently increasing growth rate of their calves.

Conclusions

This study was conducted to evaluate long-acting moxidectin and ivermectin plus clorsulon for efficacy of parasite control and also for benefits relative to growth, reproductive performance, and offspring performance in beef replacement heifers. Fecal egg count reductions indicated that LMXD had greater efficacy against gastrointestinal nematodes compared to IVCL. Average daily gains during the pre-calving period of this study were greater for LMXD and IVCL-treated heifers compared to the untreated heifers. After 63 days of breeding exposure, pregnancy rates of heifers treated with LMXD and IVCL were higher than CON heifers, but after an additional 21 days of bull exposure, there were no significant differences in pregnancy rates between treatment groups. Calves from LMXD-treated heifers had significantly higher AWW and ADG compared to calves from untreated CON heifers. Growth performance for calves from IVCL-treated heifers was not significantly different from calves of untreated heifers or from calves of LMXD-treated heifers.

Endnotes

[a]Pyramid® 10, Fort Dodge Animal Health, Overland Park, KS
[b]Presponse® SQ, Fort Dodge Animal Health, Overland Park, KS
[c]20/20 Vision®7, Intervet Inc., Millsboro, DE
[d]Micotil®, Elanco Animal Health, Greenfield, IN
[e]Oklahoma Animal Disease and Diagnostic Laboratory, Stillwater, OK
[f]Cydectin® Long-Acting Injectable, Fort Dodge Animal Health, Overland Park, KS
[g]Ivomec® Plus Injectable, Merial, Duluth, GA
[h]Cydectin® Pour-On, Fort Dodge Animal Health, Overland Park, KS
[i]Triangle® 4, Fort Dodge Animal Health, Overland Park, KS
[j]Vision® 7, Intervet Inc., Millsboro, DE

Acknowledgements

The authors would like to thank Fort Dodge Animal Health, Overland Park, KS for partially funding this project. We would also like to thank J.A. Hornsby, C. Jamison, E.B. Kegley, R. Rorie, F.D. Clark, C. Prewett, and T. Lester for their technical support.

References

1. Ballweber LR, Smith LL, Stuedemann JA, Yazwinski TA, Skogerboe TL: The effectiveness of doramectin or ivermectin in the control of gastrointestinal nematodes in grazing yearling stocker cattle. *Vet Parasit* 72:53-68, 1997.
2. Cleale RM, Hart KB, Hutchens DE, Johnson EG, Paul AJ, Smith LL, Tucker C, Yazwinski TA, Doscher ME, Grubbs ST, Wulster-Radcliffe M, Amodie DM: Effects of subcutaneous injections of a long acting moxidectin formulation in grazing beef cattle on parasite fecal egg reduction and animal weight gain. *Vet Parasit* 126:325-338, 2004.
3. DesCoteaux L, Doucet M, Caldwell V: Evaluation of the impact of parasite control with the Ivomec® SR Bolus given at breeding age on first lactation yield in Holstein heifers. *Vet Parasit* 98:309-314, 2001.
4. Geurden T, Claerebout E, Deroover E, Vercruysse J: Evaluation of chemoprophylactic efficacy of 10% long acting moxidectin against gastrointestinal nematode infections in calves in Belgium. *Vet Parasit* 120:331-338, 2004.
5. Keith RK: The differentiation of the infective larvae of some common nematode parasites in cattle. *Aust J Zool* 1:223-235, 1953.
6. Lacau-Mengido IM, Mejía ME, Díaz-Torga GS, Gonzalex Iglesias A, Formía N, Libertun C, Becú-Villalobos D: Endocrine studies in ivermectin-treated heifers from birth to puberty. *J Anim Sci* 78:817-824, 2000.
7. Loyacano AF, Williams JC, Gurie J, DeRosa AA: Effect of gastrointestinal nematode and liver fluke infections on weight gain and reproductive performance of beef heifers. *Vet Parasit* 107:227-234, 2002.
8. Ploeger HW, Kloosterman A, Rietveld FW, Hilderson H, Berghen P, Pieke EJ: Production of dairy replacement stock in relation to level of exposure to gastrointestinal nematode infection in the first grazing season: second-year calves and heifers. *Vet Parasit* 65:99-115, 1996.
9. Purvis HT, Whittier JC, Boyles SL, Johnson LJ, Ritchie HD, Rust SR, Faulkner DB, Lemenager RP, Hendrix KS: Weight gain and reproductive performance of spring-born beef heifer calves intraruminally administered oxfendazole. *J Anim Sci* 72:817-823, 1994.
10. Ryan W, Brown J, Corah L, Coornbos D, Loyacano A, Spire M: Evaluation of the impact of ivermectin treatment on the growth and reproductive performance of replacement heifers. *Proc XVII World Buiatrics Cong and Proc Am Assoc Bov Pract Conf* 25:23-38, 1992.
11. Sanson DW, DeRosa AA, Oremus GR, Foil LD: Effect of horn fly and internal parasite control on growth of beef heifers. *Vet Parasit* 117:291-300, 2003.
12. SAS, 2005. SAS/STAT User's Guide, Version 9.1. SAS Inst. Inc, Cary, NC.
13. Silcox R (ed): *Guidelines for Uniform Beef Improvement Programs*, ed 8, Athens, GA. Beef Improvement Federation, 2002.
14. Stromberg BE, Vatthauer RJ, Schlotthauer JC, Myers GH, Haggard DL, King VL, Hanke H: Production responses following strategic parasite control in a beef cow/calf herd. *Vet Parasit* 68:315-322, 1997.
15. Vercruysse J, Rew RE: *Macrocyclic Lactones in Antiparasitic Therapy*. New York, CABI Publishing, 2002.
16. Wolstenholme AJ, Rogers AT: Glutamate-gated chloride channels and the mode of action of the avermectin/milbmycin anthelmintics. *Parasit* 131:S85-95, 2005.
17. Yazwinski TA, Featherston H, Tucker C, Johnson Z: Residual nematocidal effectiveness of ivermectin in cattle. *Am J Vet Res* 5:1416-1420, 1994.
18. Yazwinski TA, Tucker C, Copeland S, Yazwinski T, Guerino F: Dose confirmation of moxidectin pour-on against natural nematode infections in lactating dairy cows. *Vet Parasit* 86:223-228, 1999.
19. Yazwinski TA, Tucker CA: A sampling of factors relative to the epidemiology of gastrointestinal nematode parasites of cattle in the United States. *Vet Clin North Am Food Anim Pract* 22:501-527, 2006.
20. Yazwinski TA, Williams JC, Smith LL, Tucker C, Loyacano AF, DeRosa A, Peterson P, Bruer DJ, DeLay RL: Dose determination of the persistent activity of moxidectin long-acting injectable formulations against various nematode species in cattle. *Vet Parasit* 137:273-285, 2006.
21. Yazwinski TA, Tucker CA, Johnson ZB, Powell J: A field trial evaluation of the effectiveness and benefit of cydectin long-acting injectable and ivomec injectable as used one time in grazing stocker cattle. *Vet Ther* 7:43-51, 2006.
22. Zajac AM, Hansen JW, Whittier WD, Eversole DE: The effect of parasite control on fertility in beef heifers. *Vet Parasit* 40:281-291, 1991.