PEER REVIEWED

Effect of Two Dosage Levels of Doramectin on Health, Growth Performance and Carcass Characteristics of Finishing Beef Steers

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Abstract

Three thousand four hundred and forty-six crossbred Mexican-origin steers (average 625 lb; 284 kg) were utilized to determine the effect of administering doramectin at label-dose (full-dose) versus half-label dose (half-dose) on health, growth performance and carcass characteristics of finishing beef steers. Health parameters, growth performance and carcass quality grade did not differ between treatments. However, there was a significant difference in the proportion of carcasses classified as USDA yield grades (YG) 2, 3 and 4. A higher proportion of carcasses in the full-dose treatment were scored YG 2 ($P < 0.0001$), and a higher proportion of carcasses in the half-dose treatment were scored YG 3 ($P = 0.0014$) and YG 4 ($P = 0.0112$), suggesting steers treated with the full-dose treatment were leaner.

Résumé

Un total de 3 446 bouvillons croisés d'origine mexicaine (poids moyen 625 lbs; 284 kg) ont servi pour déterminer l'effet de l'administration de doramectine à la dose recommandée (dose complète) ou à la moitié de la dose recommandée (demi-dose) sur la santé, la performance de croissance et les caractéristiques de la carcasse de bouvillons de boucherie en finition. Les paramètres de santé, la performance de croissance et le grade de qualité de la carcasse n'étaient pas différents entre les traitements. Toutefois, il y avait une différence significative dans la proportion de carcasses avec des grades de rendement de l'USDA de 2, 3 et 4. Une plus forte proportion des carcasses dans le traitement avec dose complète avaient un grade de rendement de 2 ($p < 0.0001$) alors qu'une plus forte proportion des carcasses dans le traitement avec demi-dose avaient un grade de rendement de 3 ($p = 0.0014$) et 4 ($p = 0.0112$) suggérant que les bouvillons recevant la dose complète était moins gras.

Introduction

The pathophysiology of parasite infection and the effects of gastrointestinal parasitism on ruminant nutrition have been extensively studied.[4,6,7,10] The immunosuppressive effects of parasitism are well documented, and abomasal parasites (i.e., *Ostertagia)* exert some of the most profound effects.[5] The economic benefits of strategic deworming in calves and yearlings have also been demonstrated.[3,9,10,11] It is customary practice in North America to administer broad-spectrum anthelmintics to calves and yearlings entering a grazing program or feedlot to maximize production efficiency.

The effectiveness of an anthelmintic is often measured by the reduction of helminth parasites in the host animal, or the reduction of parasite eggs in the feces following treatment. For a product to be considered efficacious, 90% or more of a particular worm burden must be removed.[2] Doramectin was approved as a broad-spectrum endectocide in 1996. Results of doramectin dose response studies indicate that *Cooperia oncophora* is the least-sensitive nematode species, since a dosage of 200 mcg/kg body weight is required for effective control.[1] Other species, however, could effectively be controlled at lower doses. For example, *Ostertagia ostertagia* can be effectively controlled at a dose of 50 mcg/kg.[1]

In the cattle industry, where profit margins are often low, the challenge has become one of maximizing production while reducing input costs. Thus, feedlot processing protocols are often tailored to minimize cost without jeopardizing health and future economic returns. The purpose of this study was to evaluate and

compare health, growth performance and carcass characteristics between steers receiving the label dose and steers receiving a half-label dose of doramectin at the time of entry into a commercial feedlot.

Materials and Methods

Three thousand four hundred and forty-six crossbred Mexican-origin steers of similar breeding and market quality were backgrounded on four different pastures in the Kansas Flinthills prior to shipment and entry into a feedyard near Greeley, Colorado.

After feedyard arrival, the steers were moved through the processing facility in random order. Due to variations in frame size, cattle were stratified by weight into either heavy or light groups for marketing purposes. Cattle within body weight strata were randomly assigned to experimental treatments of full-dose or half-dose doramectin. Randomization was accomplished by chute order. After processing, group weights were obtained for each treatment/weight combination. The average weight per head in each pen was 554, 572, 581, 653, 665, 673 and 676 lb (252, 260, 264, 297, 302, 306 and 307 kg) for the half-dose treatment group, and 555, 569, 583, 662, 662, 662 and 679 lb (252, 258, 265, 301, 301, 301 and 308 kg) for the full-dose treatment group. The experimental unit was defined as the group of cattle receiving the same treatment within a pen. Both treatments for a given weight replicate were commingled within a pen to decrease variability in feeding conditions. A total of seven replicates were placed on study.

Processing included the experimental treatment for internal and external parasites with either half-dose (100 mcg/kg; 1 ml per 220 lb [100 kg]) or full-dose (200 mcg/kg; 1 ml per 110 lb [50 kg]) doramectin[a] injected subcutaneously; no other parasiticides were utilized during the trial. Four pre-set automatic syringes color-coded to the lot tags were used to administer doramectin. All cattle were implanted with a growth implant.[b] Since cattle had been vaccinated at arrival to the stocker pasture, no bacterins or viral vaccines were administered upon feedyard entry. Gender was confirmed for each individual and two bulls (monorchids) were found (one in each treatment group); castration was not performed.

A total of 30 random fecal samples from each treatment group were collected on the day of processing from the pen floor and submitted to Colorado State University Veterinary Diagnostic Laboratory for parasite egg counts. Samples were only collected when the investigator could visually observe the steer defecating, and therefore confirm the treatment group to which it belonged. Fifteen subsequent fresh fecal samples were randomly collected from the pen floor from each treatment group at approximately 32 days on feed and submitted to the CSU-VDL for parasite egg counts.

Steers were fed twice daily. The ration consisted of high-moisture corn, flaked corn, alfalfa hay, steep/molasses and a protein/mineral/vitamin premix. A series of three adaptation or "step-up" rations were utilized prior to the finishing ration (Table 1). At approximately 81 days on feed, steers were placed on the finishing ration that contained 12.41% crude protein (dry matter basis) and provided 300mg monensin[c] and 90mg of tylosin[d] per head daily.

Pen riders and treatment personnel were blinded to experimental treatment assignment. Cattle requiring medical attention were pulled from the home pen and placed in the hospital for treatment. Diagnosis and treatment of cattle pulled from the home pen followed the standard treatment protocol established at the feedyard. Cattle were allowed to recover in hospital pens following treatment, and were then returned to their home pen. Health records for all treated cattle were maintained throughout the trial. Bullers, defined as steers consistently ridden by penmates, were removed from their home pen and fed in a designated buller pen. Bullers were removed from the buller pen by lot for shipping and weighed separately to obtain growth performance data. Carcass data from bullers was not included in the analysis. Realizers, cattle not considered capable of reaching market weight in the same amount of time as their penmates due to illness (i.e. chronic respira-

Table 1. Feedlot ration composition (as fed).

		Percent in ration, as fed			
Ingredient	DM (%)	Ration 1	Ration 2	Ration 3	Finisher
Alfalfa hay	87.4	46.3	29.5	17.4	8.4
Flaked corn	77.1	39.9	29.3	18.0	16.3
Molasses/Steep	62.6	10.0	7.0	4.0	2.0
Starter supplement	92.3	3.8	—	—	—
High moisture corn	71.0	—	29.3	54.1	65.1
Finisher supplement	93.8	—	3.9	4.5	5.7
Tallow	99.0	—	1.0	2.0	2.5

tory disease, laminitis, urinary calculi, etc.) or due to an undiagnosed failure to thrive, were removed from the home pen and marketed via alternate channels. They were excluded from the final growth performance and carcass characteristic evaluation. All animals that died during the trial were weighed and necropsied.

Steers were slaughtered when they were visually estimated to have adequate finish for market. Days on feed ranged from 189 to 237 (average 208 days). Approximately one to two hours prior to shipment, cattle were sorted by treatment and pen weights were obtained. Both initial and final weights were single-day, full weights obtained prior to feeding. They were not adjusted for shrinkage (i.e. no "pencil shrink" was used). Cattle were separated by treatment group and shipped to a local commercial packing plant. Each treatment group was kept separate at the packing plant to assure accurate data collection. USDA plant data included hot carcass weight (HCW), quality grade and yield grade. Carcasses were hot-fat trimmed and kidney, pelvic and heart fat were removed on the slaughter floor prior to grading procedures. There were a total of seven slaughter dates, and all steers from a given pen (replicate) were slaughtered on the same day.

Statistical analysis was performed using statistical software.[e] The paired t-test was used to analyze parametric data (initial weight, final weight, average daily gain [deads included and deads out], hot carcass weight and dressing percentage). Nonparametric data (health parameters, quality grade and yield grade percentages) were analyzed using Chi-square contingency tables to test goodness of fit against a Chi-square distribution. Significant was declared at a P value of ≤ 0.05.

Results

Mean fecal egg counts are reported in Table 2. Table 3 shows the feedlot health summary. There was no statistical difference between treatments in the total proportion of animals treated ($P = 0.39$), in the proportion of bullers ($P = 0.33$), in the proportion of animals treated for respiratory disease and/or other medical conditions ($P = 0.93$), or in the total number of medical treatments ($P = 0.15$). Total treatment cost for each group and treatment cost/head for each group were not analyzed for statistical significance, but were numerically similar between treatment groups. No differences were detected in the proportion of animals that died ($P = 0.45$) or proportion of animals that were realized ($P = 0.67$). Mortality and realizers by diagnosis are depicted in Tables 4 and 5, respectively.

Feedlot growth performance data are shown in Table 6. Allotment and sorting procedures were deemed adequate since average starting weights were equivalent in both groups ($P = 0.91$). Average final weights were similar for steers in each treatment group ($P = 0.86$). Deads-in average daily gain (ADG) was calculated for each treatment by subtracting the total beginning group weight for each individual treatment group from the total ending weight divided by total head days. Individual head-day calculations accounted for those animals that died or were removed for salvage or as bullers. Deads-out ADG was computed by taking the average weight per head gained (final minus initial pen weights from individual treatment group) divided by the days on feed for each replicate. There were no significant differences between treatment groups in either of the ADG calculations (deads-in ADG: $P = 0.95$; deads-out ADG: $P = 0.64$). Dry matter intake and feed conversion data could not be captured by treatment since cattle were commingled in a pen for a given replicate.

The effects of using half-dose versus full-dose doramectin on carcass traits are presented in Table 7. There were no significant differences between treatment groups in dressing percentage ($P = 0.17$) or in hot carcass weight ($P = 0.46$). A significantly higher proportion of carcasses from the full-dose treatment were classified as YG 2 ($P < 0.0001$), and a significantly higher proportion of carcasses from the half-dose treatment were classified as YG 3 ($P = 0.0014$) and YG 4 ($P = 0.0112$).

Table 2. Median and range of fecal egg counts (eggs/g).

	Half-dose	Full-dose
Day 0[a,b]	10 (0-360)	5.5 (0-300)
Day 32[c]	0 (0-180)	0 (0-50)

[a]n=30 samples per treatment.
[b]Median (range)
[c]n=15 samples per treatment.

Table 3. Effects of using half-dose vs. full-dose doramectin at initial processing on health parameters.

	Half-dose	Full-dose	P
Total head	1728	1718	—
No. head treated	85	73	0.39
% of steers	4.9	4.2	—
Bullers	47	37	0.33
Respiratory/other	39	38	0.93
Total No. treatments	101	86	0.15
No. dead	5	2	0.45
No. realizers	10	13	0.67
Treatment cost, $	757.69	723.45	—
Treatment cost, $/hd	0.44	0.42	—

Table 4. Feedlot mortality summary.

Lot	Animal ID	Date	DOF	Trt	Diagnosis
090	r3078	8/30/01	41	Half	Undetermined
090	g2570	9/2/01	44	Half	Acute interstitial pneumonia
090	g2885	1/25/02	189	Half	Bloat
092	r3826	1/14/02	179	Full	Abomasal ulcer
098	g2856	12/16/01	151	Half	Bloat
098	g2887	1/26/02	192	Half	Bloat
114	g2849	12/11/01	139	Full	Right heart failure

DOF = days on feed at time of death

Table 5. Summary of feedlot cattle removed and realized.

Lot	Animal ID	Date	DOF	Trt	Diagnosis
82	no hosp tag	9/20/01	65	Full	Lame
82	g2564	12/4/01	140	Full	Lame
82	g2824	2/28/02	226	Full	Lame
84	r3003	9/6/01	51	Half	Chronic pneumonia
84	g2866	1/2/02	169	Half	Lame
84	g2868	1/3/02	170	Half	Lame
84	g2884	2/4/02	202	Half	Lump jaw
84	g16015	2/21/02	219	Half	Founder
86	no hosp tag	1/22/02	189	Full	Bloat
88	no hosp tag	10/11/01	86	Half	Downer
90	r2889	8/30/01	41	Full	Lame
90	g2572	9/20/01	62	Full	Abscess
90	r4025	2/18/02	213	Full	Diphtheria
90	g16023	3/6/02	229	Full	Lame
92	g2530	8/10/01	34	Full	Lame
92	g2539	9/27/01	70	Full	Brisket
92	r3816	12/20/01	154	Half	Waterbelly
112	g2708	1/11/02	170	Full	Founder
112	g2373	10/30/01	97	Half	Lame
112	r3537	12/7/01	135	Half	Chronic pneumonia
114	r2749	9/6/01	43	Full	Brisket
114	r3494	1/12/02	171	Half	Behind the pen
114	g2718	1/18/02	177	Full	Hernia

DOF = days on feed at the time of feedlot removal

The proportion of choice/prime carcasses ($P = 0.68$), select carcasses ($P = 0.13$) and carcasses designated as "no-roll" ($P = 0.08$) were not significantly different between treatment groups. Any carcasses not grading at least select were designated as no-roll. This would include dark cutters and carcasses identified with advanced skeletal maturity (hard bone) as evidenced by cartilage ossification.

Discussion

Although a quantitative fecal exam was used to determine the number of eggs/gram at initial processing and following treatment (Day 32), the authors concede that this may not be an accurate measure of anthelmintic efficacy due to variability in egg productivity of different parasite species. Fecal samples were collected to establish the presence of parasites at feedlot entry, but not to speculate on the severity of infection or to evaluate treatment efficacy. Therefore, no statistical analysis was performed on fecal egg count data.

Other researchers reported that both the number of cattle treated and the total number of medical treatments administered were reduced when steers were dewormed with fenbendazole at feedlot entry as compared to untreated controls.[11] In the current study, cattle health was not affected by the dosage of doramectin.

Table 6. Effects of using half-dose versus full-dose doramectin at initial processing on feedlot growth performance (208 days on feed).

	Half-dose	Full-dose	*P*
No. pens	7	7	—
No. steers	1728	1718	—
Initial wt (lb)[a,b]	624.6 ± 52.9	624.9 ± 53.3	0.91
Final wt (lb)[a,c]	1217.4 ± 52.6	1217.8 ± 55.6	0.86
Daily gain (lb), deads out[a,d]	2.88 ± 0.26	2.89 ± 0.26	0.64
Daily gain (lb), deads in[a,e]	2.89 ± 0.26	2.88 ± 0.40	0.95

[a]Mean ± standard deviation
[b]All initial weights recorded were full unshrunk.
[c]All final weights recorded were full unshrunk.
[d]Deads out daily gain included bullers for their respective treatment. Realizers and dead weights were not included.
[e]Deads in daily gain included bullers, realizers, and deads.

Table 7. Effects of using half-dose vs. full-dose doramectin at initial processing on carcass characteristics.

	Half-dose	Full-dose	*P*
No. of carcasses	1,666	1,666	—
Dressing pct[a,b]	64.87 ± 0.61	64.65 ± 0.44	0.17
Hot weight, lb[a,b]	758.4 ± 35.4	756.4 ± 37.7	0.46
YG Distribution[c]			
YG 2 (%)	646 (38.8)	763 (45.8)	<0.0001
YG 3 (%)	932 (55.9)	838 (50.3)	0.0014
YG 4 (%)	50 (3.0)	27 (1.6)	0.0112
YG 5 (%)	4 (0.2)	2 (0.1)	0.6828
QG Distribution[d]			
Choice/Prime (%)	1280 (76.8)	1291 (77.5)	0.68
Select (%)	312 (18.7)	278 (16.7)	0.13
No roll (%)	74 (4.4)	97 (5.8)	0.08

[a]Mean ± standard deviation
[b]Probability values for paired t-test
[c]Distribution of Yield Grades, probability values for Chi-square analysis
[d]Distribution of Quality Grades, probability values for Chi-square analysis

Previous studies have shown significant improvement in ADG and hot carcass weight in cattle treated with fenbendazole,[11] ivermectin/clorsulon,[9] or doramectin[3,9,10] when compared to cattle receiving no treatment for internal parasites. One of these studies demonstrated a significant improvement in ADG (calculated with deads excluded) and hot carcass weight in cattle treated with full-dose doramectin compared to those treated with half-dose doramectin.[3] In our study, there was no statistically significant difference in either of the ADG calculations or in hot carcass weight (Tables 6 and 7).

Quality grade-based grid marketing formulas have become a very important and profitable method to market cattle given optimal cattle genetics and marketing conditions. Therefore, the effect of management decisions on carcass traits can have a significant economic impact. Three previous studies have shown significant improvement in quality grade of carcasses of cattle dewormed at feedlot entry compared to those not dewormed.[3,10,11] An Idaho study using 60 yearling steers in each of three treatment groups showed no difference in carcass quality grade between untreated controls and two groups of cattle dewormed (doramectin or ivermectin/clorsulon) at feedlot entry.[9] Deworming steers with full-dose doramectin offered no advantage for quality grade over deworming with half-dose in our current study. This finding is in contrast to a similar study that reported a significantly higher proportion of prime and choice carcasses, and a significantly lower proportion of select carcasses, in cattle dewormed with full-dose doramectin when compared to those not dewormed or dewormed with half-dose doramectin.[3]

Carcasses from steers administered the full-dose were superior in cutability, a measure of edible lean tissue, compared to those administered the half-dose as demonstrated by the distribution of USDA yield grades (Table 7). All carcasses were hot-fat trimmed on the slaughter floor prior to grading since this was standard operating procedure for the plant. Subcutaneous fat over the ribeye (FOE) was not trimmed; therefore, FOE and preliminary yield grades were likely accurate. The higher percentage of YG 3 and YG 4 carcasses in the half-dose group would suggest these steers were fatter, but we cannot explain the reason for this. From a physiological perspective, it does not seem likely that treatment alone would account for the differences in the outcome. In previous reports, no significant differences were detected between untreated controls, full-dose and

half-dose doramectin in median YG scores,[3] or in YG distribution between untreated controls, ivermectin/clorsulon-treated cattle and doramectin-treated cattle.[9] Another study showed a significantly smaller percentage of YG 3 carcasses in calves not dewormed at either the grazing phase or at feedlot entry compared to cattle that were dewormed at either time or dewormed both times.[11]

When no statistically significant differences are seen in several outcomes of interest, a discussion of statistical power is warranted. If no significant differences are found, it is either because there is no treatment effect or because there were not sufficient experimental units (statistical power) to detect the treatment effects that existed. In the current study, no statistically significant differences were detected in several of the measured outcomes. It could be argued that with an increased number of experimental units some treatment effects in these outcomes might have been detected. However, the numerical differences between treatments in these outcomes were so small that they would not influence decisions of cattle producers and veterinarians about the use of this anthelmintic.

Conclusions

The objective of this study was to determine whether a reduced dose of doramectin would negatively impact health, growth performance or carcass quality of steers fed in a commercial feedlot setting. Health, growth performance and carcass quality parameters did not differ between treatment groups. Results of this study differ on several points from those of the prior study comparing full-dose and half-dose doramectin. This suggests that further studies are needed to determine if other factors (genetics, cattle origin, geographic location, prior de-worming history, etc.) may interact with the doramectin dose to influence health, growth performance and carcass traits. However, under the conditions of this study, there was no economic advantage to using a full dose of doramectin.

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Footnotes

[a]Dectomax®, Pfizer Animal Health, Exton, PA.
[b]Component E-S®, VetLife, West Des Moines, IA.
[c]Rumensin®, Elanco Animal Health, Indianapolis, IN.
[d]Tylan®, Elanco Animal Health, Indianapolis, IN.
[e]GraphPad Software, GraphPad Prism ver. 3.0c, San Diego, CA.

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Abstract

Duration of Efficacy of Ceftiofur Crystalline Free Acid Compared to Tilmicosin When Administered at Various Times before Intratracheal *Mannheimia haemolytica* Challenge in Calves

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Objectives

The primary objective of this study was to evaluate the duration of protection provided against bovine respiratory disease (BRD) by ceftiofur crystalline free acid sterile suspension (CCFA-SS; 200 mg ceftiofur equivalents [CE]/mL) administered as a single injection subcutaneously (SC) in the middle third of the posterior aspect of the ear of calves compared to tilmicosin. Treatments were administered at 3, 5, 7, or 9 days before intratracheal challenge with *Mannheimia haemolytica*. Secondary objectives included determining plasma ceftiofur and desfuroylceftiofur-related metabolite concentrations and serum haptoglobin concentrations at various predetermined times.

Materials and Methods

One hundred forty four (144) Holstein calves (168.7 ± 20.2 lb; 76.7 ± 9.2 kg) were randomly assigned to a challenge time group (challenge 3, 5, 7 or 9 days after treatment; n=36/challenge group) at arrival (day -4) and moved to the assigned hutch. The principal investigator (PI) remained blinded to treatments, and performed daily clinical observations of each calf beginning the day after arrival. On day 0, calves were randomized to one of three treatments: negative controls (vehicle treatment; n=6/challenge group); CCFA-SS at 3.0 mg ceftiofur equivalents/lb (6.6 mg/kg) BW administered SC in the posterior aspect of the ear (n=15/group); or tilmicosin (4.55 mg/lb [10 mg/kg]; n=15/group) within each day's challenge group. Six CCFA-SS treated calves were randomly selected from each challenge group for blood sample collection for determination of ceftiofur plasma concentrations before treatment on day 0 and on day of challenge. Additional blood samples were collected from the same six CCFA-SS calves in each challenge group, and from six randomly selected negative control and tilmicosin calves in each treatment group for determination of serum haptoglobin concentrations. Serum samples were collected on day 1, the day before challenge, the day of challenge and 1, 2, 3, 5, 7 and 9 days after challenge. The treatment administrator administered all treatments on day 0.

The day before challenge, calves were transported to a feedlot where they were wetted, branded, administered a clostridial vaccine intramuscularly and housed together in a large pen overnight before being transported back to the hutch facility for challenge. The challenge organism was isolate D9707257, originally obtained from a clinical case. The challenge was administered intratracheally as two separate challenges on the assigned day. New challenge material was prepared in BHI broth on each day challenges were administered. The first challenge consisted of 10 mL of challenge material acidified to pH of 4.5 and containing from 2.34×10^7 to 1.29×10^8 CFU/mL. The second challenge was administered four hours after the first. It was not acidified and consisted of 15 mL containing from 3.8×10^8 to 8.2×10^9 CFU/mL.

Daily evaluations continued until 9 days post-challenge, when all surviving calves were euthanized and the PI evaluated lung lesions. The primary variables were mortality due to BRD, rectal temperature and lung lesion scores 9 days after challenge. Data were analyzed using SAS's GLM procedure.

Results

Cumulative mortality due to BRD was 0, 3.3 and 33% for CCFA, tilmicosin and negative controls, respectively. The mortality rate in the negative controls provides assurance that the challenge used in this study resulted in severe BRD. On days 1, 3, 4 and 5 post-challenge, CCFA-SS calves had a lower proportion of calves that were not clinically normal compared to tilmicosin ($p<0.05$). On days 1-7 days post-challenge, 49, 23, 53, 43, 62, 43 and 7% more tilmicosin calves were determined not to be clinically normal compared to CCFA-SS calves. LSMean rectal temperatures for CCFA-SS calves were lower than tilmicosin calves through 3 days post-challenge ($p<0.05$). LSMean lung lesion scores 7 and 9 days post-challenge were 1.46 and 3.94% for CCFA-SS calves, and 4.88 and 13.7% for tilmicosin calves ($p<0.05$). Plasma concentrations of ceftiofur and desfuroylceftiofur-related metabolites were 0.94, 0.62, 0.39 and 0.19 µg/mL at 3, 5, 7 and 9 days post-treatment, respectively. These concentrations were all above the minimum inhibitory concentration (MIC) of the challenge organism (≤0.03 µg/mL). Mean serum haptoglobin concentrations on day 1 were 25 mg/100 mL. Peak serum haptoglobin concentrations were 70-97 mg/100 mL for CCFA-SS challenge groups, 121-207 for the tilmicosin challenge groups, and 142-183 for the vehicle control challenge groups.

Conclusions

A single SC administration of CCFA-SS at 3.0 mg CE/lb SC in the posterior aspect of the ear provided superior protection against BRD compared to tilmicosin when an intratracheal *M. haemolytica* challenge was administered up to 9 days after treatment administration. These results provide clinical confirmation that plasma concentrations of ceftiofur and desfuroylceftiofur-related metabolites ≥0.2 µg/mL observed for 7-9 days after CCFA-SS administration are protective against BRD infection.

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