A fenbendazole oral drench in addition to an ivermectin pour-on reduces parasite burden and improves feedlot and carcass performance of finishing heifers compared with endectocides alone[1]

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ABSTRACT: Two studies utilizing 1,862 yearling heifers were conducted to determine the effects of a fenbendazole oral drench in addition to an ivermectin pour-on (SG+IVPO), compared with an ivermectin pour-on (IVPO) or a doramectin injectable (DMX) alone, on parasite burden, feedlot performance, and carcass merit of feedlot cattle. In the first study, heifers receiving the SG+IVPO had fewer ($P = 0.02$) cattle retreated for disease and 73% fewer ($P = 0.06$) worm eggs per fecal sample 98 d after treatment than heifers treated with IVPO. Heifers treated with SG+IVPO consumed more DM, had greater ADG, were heavier at slaughter, and had heavier carcasses than IVPO-treated heifers ($P < 0.05$). Heifers treated with SG+IVPO also had more ($P = 0.07$) carcasses grading USDA Prime or Choice than IVPO-treated heifers. In the second study, heifers treated with SG+IVPO had fewer ($P < 0.01$) worm eggs per fecal sample 35 d after treatment and had fewer numbers of adult and larval *Cooperia* and *Trichostrongylus* spp. in the small intestine at slaughter ($P < 0.10$) compared with heifers treated with DMX. Heifers treated with SG+IVPO consumed more DM, were heavier at slaughter, and had heavier carcasses than DMX-treated heifers ($P < 0.01$). The SG+IVPO-treated heifers also had greater ADG ($P < 0.10$). The broad-spectrum effectiveness of a combination of a fenbendazole oral drench and an ivermectin pour-on reduced parasite burden and increased feed intake, ADG, and carcass weight in feedlot heifers compared with treatment with an endectocide alone.

Key words: doramectin, fenbendazole, finishing heifer, internal parasite, ivermectin

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INTRODUCTION

Internal parasitism of feedlot cattle has been documented to reduce performance and impair immune function (Snider et al., 1986; Wiggin and Gibbs, 1990; Gómez-Muñoz et al., 2004). Infection of cattle by *Ostertagia ostertagi* reduced feed intake, ADG, and efficiency of protein digestion (Fox et al., 1989a), and infected cattle treated with fenbendazole ate more feed than nontreated controls (Fox et al., 1989a; Smith et al., 2000). Fenbendazole has been effectively used in beef cattle to reduce internal parasitism caused by brown stomach worm (*Ostertagia ostertagi*), intestinal worms (*Cooperia* spp., *Bunostomum* spp., and *Nematodirus* spp.) and tapeworm (*Monezia;* FDA, 2003). Also, fenbendazole eliminated parasite loads more rapidly than ivermectin (Miller and Morrison, 1992) resulting in improved performance (Lee, 1985; Myers and Grant, 1988).

Due to differences in mode of action and route of delivery, anthelmintics tend to differ in their efficacy in controlling different internal parasites. For instance, fenbendazole (5 mg/kg of BW) has been shown to be effective for control of hookworm (*Bunostomum phlebotomum*) and thread-necked worm (*Nematodirus helvetianus;* FDA, 2003), which are common intestinal worms, but the topical application of an ivermectin pour-on is not approved for this use (FDA, 2004). In contrast, ivermectin is effective for the control of inhibited larvae of *Ostertagia ostertagi,* but fenbendazole is not when administered at the lowest approved dosage of 5 mg/kg of BW (FDA, 2003).

Based on the aforementioned perceived strengths and weaknesses of the different groups of anthelmintics, the objectives of these studies were to determine the impacts of treating feedlot heifers on arrival with a combination of a fenbendazole oral drench and an iver-

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mectin pour-on compared with either an ivermectin pour-on or a doramectin injectable alone on parasite burden, feedlot performance, and carcass quality of feedlot heifers.

MATERIALS AND METHODS

Research protocols followed the guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching.

Experiment 1

To compare the effect of a combination of a fenbendazole oral drench plus an ivermectin pour-on to that of an ivermectin pour-on alone on fecal egg counts, performance, and carcass traits, English × Continental, yearling heifers (n = 1,106; initial BW = 338 ± 1.2 kg) were purchased from sale barns in southern Texas and shipped to a research feedlot in Syracuse, KS (Bos Technica Research Services). Heifers arrived in 8 groups on 8 different days. The arrival date was used as the blocking factor. Within an arrival-date group, heifers were assigned randomly to 1 of 2 pens. One of 2 treatments was then assigned randomly to each pen. Heifers were not allowed access to feed or water during the allotment process. The first block was assigned to treatment on June 16, 2003, and the last block was assigned on July 18, 2003.

Immediately after assignment, each pen of heifers was processed and subsequently weighed as a group, providing the initial BW. The 16 pens averaged 69 heifers in each (63 to 73 per pen). Each heifer was identified at processing with 2 uniquely numbered ear tags, implanted with Finaplix-H (Intervet Inc., Millsboro, DE) and vaccinated with a modified-live virus respiratory vaccine containing IBR, BRSV, PI3, BVD Type 1 and BVD Type 2, and a 7-way clostridial bacterin-toxoid. Treatments, administered on d 0, were 1) a fenbendazole (Safeguard, Intervet Inc., Millsboro, DE) oral drench (5 mg of fenbendazole/kg of BW) and an ivermectin (Ivomec, Merial, Duluth, GA) pour-on (500 μg of ivermectin/kg of BW; **SG+IVPO**), and 2) an ivermectin pour-on (500 μg of ivermectin/kg of BW) alone (**IVPO**).

Fresh fecal samples were collected 3 times during the study: 1) as animals were allocated to pens and before assignment of treatment, d 0; 2) midway through the study (range of d 71 to 111; average of 98-d posttreatment); and 3) at slaughter. Initially 20% of the heifers (every fifth animal through the chute) from each pen were sampled on arrival and 10% of the heifers in each pen were randomly sampled on d 98 and at slaughter for fecal worm egg counts. Individual fresh fecal samples were collected and sealed in plastic bags, identified, and sent in an insulated container with an ice pack to an independent laboratory (Animal Production Consulting, Lincoln, NE) for analysis of parasite eggs using the Modified Wisconsin Sugar Flotation Technique (Cox and Todd, 1962). The laboratory technician was blinded to treatment assignments.

Heifers were brought to full-feed using 3 step-up rations, with the diet being changed every 7 d. The final ration consisted of a mixture of steam-flaked corn, alfalfa hay, cane molasses, fat, and supplement, and contained approximately 36.3 g/ton of monensin and 11 g/ton of tylosin (DM basis; Table 1). Melengestrol acetate was also included in the final ration at 0.40 mg/heifer daily. The final diet was formulated to contain 12.5% CP, 7.4% fat, 5.7% crude fiber, 0.65% Ca, and 0.31% P (DM basis).

Animals were monitored twice daily for clinical signs of respiratory disease or injury. Of the heifers observed to be morbid, those with rectal temperatures exceeding 39.7°C were treated as prescribed by a veterinarian. The percentage of apparent morbidity was calculated as the number of animals removed from the home pen for symptoms of apparent morbidity divided by the total number of cattle in the pen. The percentage of respiratory morbidity was calculated as the number of cattle with rectal temperatures exceeding 39.7°C and displaying symptoms of respiratory disease, as determined by a trained evaluator, divided by the total number of cattle in the pen.

Heifers were slaughtered on November 4 (3 blocks, 6 pens) and 20 (5 blocks, 10 pens) of 2003, averaging 135 d on feed. Before shipment to the slaughter plant, each pen of heifers was weighed as a group to determine final live BW. Because previous studies at this facility have been evaluated on a shrunk BW basis, final live BW was decreased by 4%. Carcass data was collected by trained carcass collection personnel, and included HCW, USDA Yield Grade, marbling score, USDA Quality Grade, and percentage dark cutters.

Data (initial BW, final BW, ADG, DMI, G:F, HCW, USDA Yield Grade, USDA Quality Grade, dark cutters, apparent morbidity, apparent respiratory morbidity, retreatment, retreatment for respiratory morbidity, mortality, mortality due to respiratory disease, initial egg count, intermediate egg count, and slaughter egg count) were analyzed as a randomized complete block design (Statistix, version 8, 2002) with 2 treatments and 8 blocks. Pen served as the experimental unit. Pens were weighed together on pen scales to determine initial and final BW, but all other variables were measured on individual animals or carcasses, and arithmetic pen means were used for statistical analysis. Model effects included treatment and block, with treatment as a fixed effect and block as a random effect. Means were separated using LSD, and treatment means were considered different when the *F*-test had a *P* value ≤0.10 and a tendency when the *P* value was ≤0.15 but >0.10.

Experiment 2

To compare the effect of a combination of a fenbendazole oral drench plus an ivermectin pour-on to that of a doramectin injectable alone on parasite loads, performance and carcass traits of finishing cattle, English × Continental yearling heifers (n = 756; initial BW 318

± 1.6 kg) were delivered from wheat-native summer pasture in northeastern Oklahoma to a commercial feedyard in eastern CO. Upon arrival at the feedyard, heifers were randomly assigned (5 heifers at a time) to each of 18 pens until all pens contained 40 heifers, when the remaining heifers were allotted randomly (2 heifers at a time) to each pen. The 18 pens contained 42 heifers/pen. Treatments were then randomly assigned to the 9 adjacent pairs of pens. Heifers were not allowed access to feed or water during the allotment process. Heifers were assigned to treatment on June 2, 2004.

Immediately after assignment each pen of heifers was weighed as a group, providing the initial BW. Each heifer was identified at processing with 2 uniquely numbered ear tags, implanted with Revalor-200 (Intervet Inc., Millsboro, DE), and vaccinated with a modified-live virus respiratory vaccine (IBR-BVD type 1 and 2). Treatments, administered on d 0, were 1) a fenbendazole (5 mg/kg of BW) oral drench and an ivermectin (500 μg/kg of BW) pour-on (SG+IVPO), and 2) a doramectin (Dectomax, Pfizer Inc., New York, NY; 200 μg/kg of BW) injectable alone (**DMX**).

Fresh fecal samples were collected 3 times during the study: 1) as animals were allotted to pens and before assignment of treatment, d 0; 2) 35 d posttreatment; and 3) 99 d posttreatment. Initially, 7 heifers from each pen were randomly selected and sampled on arrival, and 6 heifers from each pen were randomly sampled on d 35 and 99 for fecal worm egg counts. Individual fresh samples were collected, processed, and analyzed as described for Exp. 1.

Heifers were brought to full-feed using 5 step-up rations, with the rations being changed every 5 d. The final ration consisted of a mixture of steam-flaked corn, alfalfa hay, corn silage, wet distiller's grains, and liquid supplement, and contained approximately 36.3 g/ton of monensin and 7.7 g/ton of tylosin (DM basis; Table 1). Melengestrol acetate was also included in the final ration to supply 0.4 mg/heifer daily. The final diet was formulated to contain 13.3% CP, 4% fat, 5.2% crude fiber, 0.79% Ca, and 0.32% P (DM basis).

Animals were monitored for disease and treated as described in Exp. 1.

Heifers were slaughtered on November 2, 2004, after 153 d on feed. Final live BW was calculated as described for Exp. 1. Carcass data was collected by trained carcass collection personnel, and included HCW, USDA Yield Grade, marbling score, and USDA Quality Grade.

Ten animals from each treatment were randomly selected (1 animal from 8 pens/treatment and 2 animals from 2 pens/treatment for a total of 20 heifers) at slaughter for enumeration of parasites in the abomasum and small intestine. Abomasums and small intestines were washed in tap water, and the mucosa was rubbed lightly to remove adhering digesta. Contents were brought to volume with 4 L of tap water, and a 10% aliquot was collected and preserved for parasite enumeration. The washed abomasum was then soaked in 4 L of tap water at room temperature for approximately 12 h, after which time the mucosa was vigorously rubbed to remove all mucus and sloughing tissue (Taylor et al., 2000). An aliquot (1 L) of this material was also collected and preserved for parasite enumeration (Ritchie et al., 1966). The laboratory technician enumerating parasites was blinded to the treatments.

Table 1. Experimental diets used to evaluate anthelmintic treatments

Ingredient	Exp. 1	Exp. 2
	% of DM	
Steam-flaked corn	82.8	71.3
Corn silage	—	13.5
Wet distiller's grains	—	5.5
Alfalfa hay	5.1	4.0
Cane molasses	2.5	—
Tallow	3.8	—
Dry supplement[1]	5.9	—
Liquid supplement[2]	—	5.7
DM	79.16	65.49
CP	12.52	13.33
Ca	0.65	0.79
P	0.31	0.32
Monensin, g/ton	36.3	36.5
Tylosin, g/ton	—	7.3
Tylosin, mg/heifer daily	90	—
Melengestrol acetate, mg/heifer daily	0.40	0.40

[1]65.99% CP, 42.98% NPN, 9.24% Ca, 1.00% P, 0.54% K, 4.31% salt, 117,421 IU/kg of vitamin A, 11,783 IU/kg of vitamin D, and 117 IU/kg of vitamin E.
[2]57.97% CP, 55.07% NPN, 10.49% Ca, 0.27% P, 2.99% K, 6.27% salt, 86,273 IU/kg of vitamin A, and 319 IU/kg of vitamin E.

Data (initial BW, final BW, ADG, DMI, G:F, HCW, USDA Yield Grade, USDA Quality Grade, dark cutters, worm count, initial egg count, intermediate egg count, slaughter egg count, apparent morbidity, apparent respiratory morbidity, retreatment, retreatment for respiratory morbidity, mortality, and mortality due to respiratory disease) were analyzed as a completely randomized design (Statistix, version 8, 2002) with 2 treatments. Pen served as the experimental unit. Initial BW and final BW were taken on a pen basis, but all other variables were measured on individual animals or carcasses, and arithmetic pen means were used for statistical analysis. Model effects included treatment. Means were separated as described for Exp. 1. Parasite enumeration data were analyzed using χ^2 test of the $\log_{10}$ transformations of actual counts.

RESULTS AND DISCUSSION

Pretreatment fecal parasite egg shedding averaged 32.7 and 8.7 worm eggs/g of fecal sample in studies 1 and 2, and there was no difference between treatments (Tables 2 and 3, respectively). Heifers treated with SG+IVPO had fewer ($P < 0.10$) parasite eggs/sample 98 d posttreatment and fewer ($P < 0.10$) eggs at slaughter compared with IVPO heifers (Table 2). Heifers treated with SG+IVPO had fewer ($P < 0.01$) eggs/sample at 35 d posttreatment than DMX-treated heifers (Table 3).

Table 2. Effects of anthelmintic treatments on fecal egg counts and health data of feedlot heifers after arrival (Exp. 1)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Ivermectin pour-on[2]	SEM	*P*-value
No. of pens	8	8		
Heifers, No.	551	555		
Days on feed	135	135		
Initial BW, kg	338	337	1.24	0.83
Fecal egg count[3]				
Initial	30.3	34.7	4.66	0.52
d 98	1.12	4.15	1.11	0.06
Slaughter	2.17	6.82	1.67	0.06
Health data				
Total apparent morbidity,[4] %	19.69	24.32	1.86	0.12
Respiratory morbidity,[5] %	18.00	22.50	2.17	0.19
Total repulls, %	47.07	58.81	2.63	0.02
Respiratory repull, %	43.95	53.82	3.32	0.07
Total mortality, %	1.26	2.14	0.58	0.32
Respiratory mortality,[6] %	0.90	1.60	0.44	0.30
Number of dead	7	12		
Respiratory dead	5	9		

[1]Fenbendazole was delivered on arrival as a liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival at the rate of 500 μg of ivermectin/kg of BW.
[3]Fecal egg counts measured per gram of sample using the Modified Wisconsin Sugar Flotation Method.
[4]Percentage of cattle pulled from home pens due to apparent disease symptoms (respiratory, as well as other diseases).
[5]Determined by rectal temperatures (>39.7°C) and clinical symptoms evaluated by trained technicians.
[6]Determined by postmortem analysis.

Table 3. Effects of anthelmintic treatments on fecal egg counts and health data of feedlot heifers (Exp. 2)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Doramectin injectable[3]	SEM	*P*-value
No. of pens	9	9		
Heifers, No.	378	378		
Days on feed	153	153		
Initial BW, kg	320	316	1.59	0.19
Fecal egg counts[4]				
Initial	9.7	7.3	1.61	0.52
d 35	0.03	1.05	0.18	<.01
d 99	0.56	0.56	0.16	1.00
Health data				
Total apparent morbidity,[5] %	5.56	4.23	0.91	0.49
Respiratory morbidity,[6] %	3.70	2.65	0.69	0.46
Total mortality,[7] %	0.53	0.79	0.44	0.69
Respiratory mortality,[8] %	0.27	0.53	0.29	0.66
Number of dead	2	3		
Respiratory dead	1	2		
Number of rejects	1	1		

[1]Fenbendazole was delivered on arrival as Safe-Guard liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival as Ivomec pour-on at the rate of 500 μg of ivermectin/kg of BW.
[3]Doramectin injectable was delivered on arrival as Dectomax at the rate of 200 μg of doramectin/kg of BW.
[4]Fecal egg counts measured per gram of sample using the Modified Wisconsin Sugar Flotation Method.
[5]Pulled from home pens for apparent symptoms of disease (respiratory as well as other diseases).
[6]Determined by rectal temperatures (>39.7°C) and clinical symptoms evaluated by trained technicians.
[7]Death loss includes chronic sick animals removed from the study before termination of the study.
[8]Determined by postmortem analysis.

Table 4. Effects of anthelmintic treatments on feedlot performance of heifers (Exp. 1)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Ivermectin pour-on[2]	SEM	*P*-value
No. of pens	8	8		
Heifers, No.	551	555		
Days on feed	135	135		
Initial BW, kg	338	337	1.24	0.83
Final BW,[3] kg	546	538	1.66	0.01
ADG, kg	1.54	1.48	0.01	0.01
DMI, kg	8.09	7.89	0.06	0.04
d 1 to 30[4]	6.07	5.82	0.08	0.07
G:F	0.190	0.188	0.001	0.22

[1]Fenbendazole was delivered on arrival as Safe-Guard liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival as Ivomec pour-on at the rate of 500 μg of ivermectin/kg of BW.
[3]Final live BW decreased by 4% to account for shrink.
[4]Dry matter intake for d 1 to 30.

Table 5. Effects of anthelmintic treatments on feedlot performance of heifers (Exp. 2)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Doramectin injectable[3]	SEM	*P*-value
No. of pens	9	9		
Heifers, No.	375	374		
Days on feed	153	153		
Initial BW, kg	320	316	1.59	0.19
Final BW,[4] kg	546	533	2.75	<0.01
ADG, kg	1.48	1.42	0.016	0.06
DMI, kg	10.34	9.83	0.089	<0.01
G:F	0.143	0.144	0.001	0.67

[1]Fenbendazole was delivered on arrival as Safe-Guard liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival as Ivomec pour-on at the rate of 500 μg of ivermectin/kg of BW.
[3]Doramectin injectable was delivered on arrival as Dectomax at the rate of 200 μg of doramectin/kg of BW.
[4]Final live BW decreased by 4% to account for shrink.

The reduction in fecal egg shedding in feedlot heifers treated with the combination of SG+IVPO compared with either IVPO or DMX alone is consistent with previously reported results. Bliss et al. (1991) demonstrated that worm egg counts in cattle treated with fenbendazole dropped below 1 egg/g in 48 to 60 h, whereas egg counts in cattle treated with ivermectin injectable dropped below 1 egg/g only after 5 d posttreatment. Similarly, Miller and Morrison (1992) reported worm egg and larvae numbers 24 h posttreatment with fenbendazole dropped 84.6 and 99.7%, respectively, compared with 73.6 and 74.8% reductions for cattle injected with ivermectin. Conversely, Conder et al. (1998) reported that topical administration of 500 μg of doramectin/kg of BW was greater than 99% effective at reducing parasite egg shedding compared with saline-treated controls.

Although mortality in these studies did not differ ($P = 0.32$ and 0.69, Exp. 1 and 2 respectively) between treatments, heifers treated with SG+IVPO tended ($P < 0.15$; Table 2) to have less apparent morbidity at 19.7% than IVPO heifers at 24.3% (SEM = 1.86), and SG+IVPO resulted in fewer ($P < 0.05$) cattle retreated for disease with 47.7% than IVPO heifers at 58.8% (SEM = 2.63). These data support the results observed by Smith et al. (2000) who reported lower morbidity and mortality in steers treated with fenbendazole before and during the grazing phase and on arrival at the feedlot compared with negative controls.

Treatment with SG+IVPO positively affected animal performance when compared with IVPO (Table 4). Heifers treated with SG+IVPO consumed more DM than IVPO heifers during the first 30 d on test ($P < 0.10$) and for the duration of the study ($P < 0.05$). Heifers treated with SG+IVPO also gained more weight and had heavier final BW ($P < 0.05$) than heifers treated with IVPO. In the second study, heifers treated with SG+IVPO consumed more DM than DMX heifers, gained more weight ($P < 0.10$), and had heavier final BW ($P < 0.05$) than heifers treated with DMX (Table 5). There was no difference in feed conversion due to treatment in either study. In both of the present studies, the combination of SG+IVPO increased DMI and ADG. Fox et al. (1989a) demonstrated that an experimentally induced challenge with *Ostertagia ostertagi* in cattle reduced feed intake, efficiency of protein digestion, and BW gain. Infected animals in that study were treated with fenbendazole on d 46 resulting in an immediate increase in feed intake. This intake-stimulation effect occurs relative to the level of infection, as demonstrated by Smith et al. (2000) where cattle treated with fenbendazole upon entering the feedyard had even greater intake and gain response to fenbendazole vs. controls if they had high (47 eggs/g) vs. low (9 eggs/g) worm egg counts.

Anorexia of parasite-infected calves may be explained by reduced feed digestion and passage. Fox et al. (1989b) reported reduced levels of blood gastrin and pepsinogen in calves artificially infected with *Ostertagia ostertagi* compared with noninfected controls. The artificially infected calves also displayed a reduction in apparent diet digestibility and digesta rate of passage (Fox et al., 1989a). This is in agreement with Sykes and Coop (1977) who noted a reduction in voluntary feed intake and apparent nitrogen digestibility in sheep experimentally infected with *Ostertagia circumcincta*. Reduced protein digestion can be partially accounted for by reduced secretions from the acid-producing parietal cells and pepsinogen-secreting chief cells due to damage by parasites (Armour et al., 1966; McLeay et al., 1973). Reductions in intake of abomasally parasitized calves has been associated with elevated blood gastrin concentrations (Fox et al., 2002), which may adversely affect reticulo-ruminal motility and abomasal emptying, leading to reduced feed intake. However, intestinal parasitism may also adversely affect feed con-

Table 6. Effects of anthelmintic treatments on carcass performance of heifers (Exp. 1)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Ivermectin pour-on[2]	SEM	*P*-value
HCW, kg	338	333	1.11	0.01
Dressing %	62.0	61.9	0.10	0.51
Yield Grade				
1 and 2, %	59.8	63.3	1.3	0.09
3, %	32.6	31.4	0.87	0.34
4 and 5, %	7.6	5.3	1.18	0.22
Avg Yield Grade	2.85	2.75	0.04	0.10
USDA Quality Grade				
Marbling Score[3]	397	389	3.33	0.13
Prime, %	0.8	0.2	0.41	0.34
Choice, %	47.1	42.4	2.0	0.13
Prime and Choice, %	47.9	42.5	2.0	0.10
Select, %	43.6	46.8	2.3	0.35
Standard, %	8.5	10.7	0.76	0.09
Dark cutters, %	0.19	0.77	0.19	0.07

[1]Fenbendazole was delivered on arrival as Safe-Guard liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival as Ivomec pour-on at the rate of 500 μg of ivermectin/kg of BW.
[3]300 = Slight^0; 400 = Small^0; 500 = Modest^0.

sumption via central satiety signals (Fox, 1997), but this mechanism is not fully understood.

Hot carcass weight was increased ($P < 0.05$) for SG+IVPO- compared with IVPO-treated heifers (Table 6) and for SG+IVPO- compared with DMX-treated heifers ($P < 0.05$; Table 7). There was no effect of treatment on dressing percent among heifers in either study. In Exp. 1, the percentage of USDA Prime or Choice carcasses tended to be increased ($P < 0.15$) and USDA Standard carcasses were reduced ($P < 0.10$) in the SG+IVPO-treated heifers (Table 4), and marbling score tended to be greater ($P < 0.15$) for heifers treated with SG+IVPO vs. IVPO. Carcasses from the SG+IVPO heifers tended to have greater ($P < 0.15$) average yield grades and had fewer USDA Yield Grade 1 or 2 ($P < 0.10$) carcasses compared with IVPO heifers. In Exp. 2, USDA percentage grading Prime and Choice ($P = 0.46$) and USDA average Yield Grade ($P = 0.20$) were not affected by treatment. However, the SG+IVPO heifers had a greater ($P < 0.10$) percentage of Yield Grade 4 and 5 carcasses compared with DMX alone. The increased degree of body fat in heifers treated with SG+IVPO is consistent with the noted increase in DMI. As SG+IVPO-treated heifers consumed more energy throughout the study and had greater ADG, it is reasonable that they would exhibit greater fat and marbling deposition. Heifers treated with SG+IVPO had a lower percentage of dark cutting carcasses than IVPO or DMX ($P < 0.10$).

Table 7. Effects of anthelmintic treatments on carcass performance of heifers (Exp. 2)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Doramectin injectable[3]	SEM	*P*-value
HCW, kg	354	346	1.6	0.01
Dressing %	64.8	65.0	0.10	0.24
Yield Grade				
1 and 2, %	53.5	55.4	1.6	0.57
3, %	38.1	40.2	2.0	0.63
4 and 5, %	8.3	4.4	1.1	0.07
Avg Yield Grade	2.85	2.78	0.02	0.20
USDA Quality Grade				
Prime, %	0.8	0.3	0.30	0.42
Choice, %	51.9	49.0	2.1	0.51
Prime and Choice, %	52.7	49.3	2.3	0.46
Select, %	44.4	48.1	2.1	0.40
Standard, %	2.9	2.7	0.64	0.85
Marbling score[4]	493	500	2.5	0.20
Dark cutter, %	0.5	2.1	0.004	0.06

[1]Fenbendazole was delivered on arrival as Safe-Guard liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival as Ivomec pour-on at the rate of 500 μg of ivermectin/kg of BW.
[3]Doramectin injectable was delivered on arrival as Dectomax at the rate of 200 μg of doramectin/kg of BW.
[4]400 = Slight^{00}; 500 = Small^{00}.

In Exp. 2, abomasal counts of adult and 4th stage larval (L_4) *Ostertagia ostertagi* were not affected by treatment ($P = 0.25$ and 0.33, respectively; Table 8). Small intestinal counts of total adult parasites, L_4 and adult *Cooperia* spp., and adult *Trichostrongylus colubriformis* were reduced ($P < 0.05$) in heifers treated with SG+IVPO compared with DMX, but total counts of *Trichostrongylus colubriformis* were not affected by treatment. The reductions in posttreatment egg shedding for SG+IVPO compared with IVPO (Exp. 1) and DMX (Exp. 2) and small intestinal adult and larval parasites for SG+IVPO-treated heifers vs. DMX-treated heifers may be interpreted to mean that the combination of a fenbendazole oral drench with ivermectin was more effective in reducing overall parasite burden than a single treatment with an avermectin. The efficacy of SG+IVPO as measured by reductions in small intestinal adult and larval stages of *Cooperia* and adult stage of *Trichostrongylus* spp. is supported by Taylor et al. (2000) who reported that treatment with fenbendazole reduced total abomasal parasite counts from 1,572/animal to 324/animal at slaughter after 121 d on feed. This reduction in parasite load was associated with increased ADG, improvement in G:F, and an increase in HCW. In a 4-experiment summary, Myers and Grant (1988) found that feedlot cattle treated with fenbendazole plus organophosphate had improved G:F compared with cattle receiving ivermectin injectible alone. In contrast, a study conducted by Guichon et al. (2000) demonstrated that cattle treated with fenbendazole, permethrin, and fenthion had a reduction in ADG compared with an ivermectin pour-on alone.

Williams et al. (1997) reported that an ivermectin pour-on (500 μg/kg of BW) possessed greater efficacy against *Ostertagia ostertagi* than fenbendazole, albendazole, or oxfendazole; however, an ivermectin pour-

Table 8. Effects of anthelmintic treatments on abomasal and intestinal parasite counts for heifers (Exp. 2)

Item	Fenbendazole[1] + ivermectin pour-on[2]	Doramectin injectable[3]	SEM	*P*-value
Number of heifers	10	10		
Abomasal count[4,5]				
Adults	1,864	848	452	0.25
L_4[6]	226	102	70	0.33
Total abomasal count	2,090	950	484	0.38
Head parasite free/total head	3/10	4/10		
Small intestinal count[4,5]				
Adult				
Total	0	2,180	719	<0.01
Trichostrongylus colubriformis	0	890	322	0.03
Cooperia spp.	0	1,290	402	<0.01
L_4				
Total	16	245	60	0.10
Trichostrongylus colubriformis	16	20	13	0.98
Cooperia spp.	0	225	56	0.03
Total small intestinal count	16	2,425	751	<0.01
Head parasite free/total head	9/10	3/10		
Total count	2,106	3,375	840	0.68

[1]Fenbendazole was delivered on arrival as Safe-Guard liquid suspension at the rate of 5 mg of fenbendazole/kg of BW.
[2]Ivermectin pour-on was delivered on arrival as Ivomec pour-on at the rate of 500 μg of ivermectin/kg of BW.
[3]Doramectin injectable was delivered on arrival as Dectomax at the rate of 200 μg of doramectin/kg of BW.
[4]*Ostertagia ostertagi.*
[5]Analyzed as $\log_{10}$ transformation of parasite counts.
[6]4th stage larvae.

on had lower efficacy against *C. punctata* adult males compared with the benzimidazoles. In cattle that had previously received multiple treatments with avermectin/milbemycin compounds, Fiel et al. (2001) reported that fenbendazole reduced egg shedding by 100% vs. pretreatment levels, compared with reductions of 85 and 65% for injectable administration of doramectin and ivermectin. Also, postmortem parasite enumeration of these same animals indicated that ivermectin was only 62.7% effective at reducing *C. oncophora.* At 200 μg/kg of BW (40% of labeled dosage) an ivermectin pour-on was reported by Alva-Valdes et al. (1986) to be 86 and 85% effective against *C. punctata* and *Trichostrongylus colubriformis.* Bliss et al. (1991) reported improved efficacy of fenbendazole compared with ivermectin injectable in reducing adult and larval stages of *Trichostrongylus axei* and *Cooperia* spp.; however, the ivermectin was administered at 100 μg/kg of BW, or one-half the labeled dosage. Conversely, Couvillion et al. (1997) demonstrated injectable doramectin was greater than 99% effective against the adult and L_4 stages of *Cooperia* spp. and *T. colubriformis.*

Improvements in performance and carcass weight in the SG+IVPO heifers can be directly attributed to greater DM and energy consumption in both of our studies. The lower fecal egg shedding posttreatment (Studies 1 and 2) and fewer parasites in the small intestine at slaughter (Exp. 2) for the SG+IVPO-treated heifers compared with heifers treated with either avermectin alone demonstrate the effectiveness of a combination of fenbendazole with an avermectin for reducing parasite loads in comparison with an avermectin alone. Whereas posttreatment fecal egg counts for the avermectin-treated heifers were not extremely high, egg counts as low as 9 eggs/g have been shown to significantly reduce performance in yearling cattle fed for slaughter (Smith et al., 2000).

These studies could be interpreted to indicate that anthelmintics of differing chemical structure and delivery method used in combination may be more effective at reducing total parasite burden than a single anthelmintic used alone. The result of more rapid and more thorough reduction of an animal's parasite load may have a beneficial impact on feed intake and performance of feedlot cattle. Also, these studies may indicate that relatively low-level parasite infections by organisms other than *Ostertagia ostertagi,* measured by fecal egg shedding or by postslaughter parasite enumeration, may have adverse effects on animal performance.

These data indicate that there may be an advantage in performance when a fenbendazole oral drench and an ivermectin pour-on are used in combination compared with using an ivermectin pour-on or a doramectin injectable alone. Heifers treated with a combination of a fenbendazole oral drench and an ivermectin pour-on consumed more feed, gained more weight, and had

heavier carcasses than heifers treated with an endectocide alone. Further studies are needed to more completely understand specific strengths and weaknesses of different types of anthelmintics and the potential economic implications of such.

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