Journal of Animal and Veterinary Advances 5 (1) : 70-76, 2006

Effects of Chlortetracycline (CTC) and Revalor-s® on Growth Performance and Carcass Quality Traits of Finishing Beef Steers

[1]S.E. Kitts, [1]D.L. Harmon, [1]E.S. Vanzant and [1,2]K.R. McLeod
[1]University of Kentucky, Lexington, KY 40546

Abstract: The objective of the current study was to ascertain the effects of Chlortetracycline (CTC) and Revalor-S, both alone and in combination, on growth performance and carcass merit of finishing beef steers. Ninety-six English-Continental crossbred steers (401 kg ± 1) were blocked according to Body Weight (BW) and pens were assigned randomly to a 2 x 2 factorial arrangement of treatments of either 0 or 39.6 ppm (DM basis) CTC/d, with and without Revalor-S. Steers received ad libitum amounts of a 90:10 concentrate-forage diet formulated to provide 105% of the Metabolizable Protein (MP) requirement for steers gaining 1.60 kg d^{-1} during d 1-62, and 1.20 kg d^{-1} during d 63-139. Steers were slaughtered on d 126 or 140 to determine carcass quality characteristics. Growth and feedlot performance data were adjusted to reflect a 139-d feeding period. During d 1-84 of the experiment, Revalor-S increased average daily gain (ADG; $p \leq 0.01$) by an average of 25% and efficiency of gain ($p \leq 0.004$) by an average of 27% relative to non-implanted steers. There were no effects ($p \geq 0.13$) of CTC on ADG or feed efficiency during d 1-84; however, dry matter intake (DMI) decreased ($p \leq 0.01$) during d 29-56 for steers receiving CTC compared to those receiving no CTC. During d 85-139, there was an interaction ($p \leq 0.07$) between CTC and implant for ADG and feed efficiency. In the absence of CTC, implanted steers gained an average of 0.74 kg d^{-1} more BW ($p \leq 0.02$), and 60% more efficiently ($p \leq 0.02$) than non-implanted steers. However, in the presence of CTC, there was no effect ($p \leq 0.13$) of implant. Treatment did not affect carcass quality ($p \leq 0.22$). Across the 139-d feeding period, implant increased ADG ($p < 0.0001$), while CTC decreased DMI ($p \leq 0.02$). Efficiency of BW gain was greater for implanted steers in the absence, but not in the presence, of CTC (CTC x implant interaction, $p \leq 0.03$). This experiment shows that Revalor-S increases ADG, however, efficiency of gain is partially diminished when subtherapeutic levels of CTC are fed in conjunction with this implant.

Key words: Chlortetracycline, growth, Implant, bovine

INTRODUCTION

Subtherapeutic feeding of Chlortetracycline (CTC) has been shown to have growth-promoting effects for ruminants, swine, and poultry, but the mechanisms responsible for these effects are not known. Most hypotheses for growth promotion by antibiotics in ruminants relate to effects on digestive tract microorganisms or gut wall thinning[1]. Based on the effects of CTC on carcass composition of calves, it has been suggested that CTC may influence growth via an endocrine axis[2]. Previously we have shown that chronic, oral administration of 350 mg CTC per steer per day elevated circulating IGF-1[3] concentrations and reduced plasma concentrations of Growth Hormone (GH), Thyroid-Stimulating Hormone (TSH), and Thyroxine (T_4) following injection of Thyrotropin-Releasing Hormone (TRH) and Growth Hormone-Releasing Hormone (GHRH) in beef steers[4]. Corresponding with these shifts in circulating hormone concentrations and sizes of the releasable pools were increases in both subcutaneous and intramuscular fat deposition [5]. However, more recently we showed that oral administration of CTC over a 112-d period did not attenuate the release of GH or TSH in response to TRH + GHRH challenges conducted at d 30, 56, and 106 and although CTC had no effect on subcutaneous fat deposition, intramuscular fat deposition tended to be greater in CTC-fed steers[6], submitted).

Implants containing estradiol and either progesterone or trenbolone acetate are used in finishing beef steers to improve feed efficiency and enhance lean tissue growth. Research has indicated increases in hot carcass weight (HCW), improved Average Daily Gain (ADG) and feed efficiency, as well as greater longissimus dorsi areas with the use of anabolic implants in finishing programs for beef cattle[7-11]. However, it has also been demonstrated that marbling scores are lower for cattle receiving growth implants, resulting in a lower percentage of carcasses grading Choice [10,11]. Current carcass pricing grids provide incentive for the development of nutritional

Corresponding Author: Kyle R. McLeod, University of Kentucky, Lexington, KY 40546 Tel : 859 257 2892 Fax: 859 257 3412

strategies to improve the carcass grades of finished cattle from Select to Choice (Select = slight amount of intramuscular fat, Choice = moderate amount of intramuscular fat[12].

Although research has shown effects of CTC and anabolic implants on growth in cattle, there is a paucity of information on effects of CTC on growth performance and carcass characteristics when fed in conjunction with anabolic implants. Therefore, the objective of the current experiment was to determine if CTC and an anabolic implant containing estradiol benzoate + trenbolone acetate interact to affect growth performance and carcass characteristics of finishing beef steers. Specifically, we challenged the proclivity of CTC to promote marbling using an aggressive implant strategy that would enhance protein accretion and tend to oppose intramuscular fat deposition.

MATERIALS AND METHODS

Animals and Treatments: The protocol for the research discussed in this report was approved by the University of Kentucky Institutional Animal Care and Use Committee. Ninety-six English-Continental crossbred steers were purchased from a commercial sale yard in Central Kentucky. After arriving at the University of Kentucky Animal Research Center, steers were dewormed using ivermectin (Merial, Duluth, GA), and vaccinated using Bovi-Shield™4 and Ultrabac®7 (Pfizer Animal Health, Exton, PA). Steers were housed in group pens (5 steers per pen) for a 56-d backgrounding period during which they had ad libitum access to a 65:35 concentrate-forage diet. The group pens measured 14.6 x 2.4 m and were located on a concrete pad partially covered with a roof. The steers had continuous access to automatic waterers.

Table 1: Experimental diets

	d 0-62		d 63-139	
Ingredient, % DM	-CTC	+CTC	-CTC	+CTC
High moisture corn	53.90	53.90	53.90	53.90
Cracked corn	19.57	19.57	19.57	19.57
Alfalfa haylage	10.06	10.06	10.06	10.06
Corn silage	5.03	5.03	5.03	5.03
Feather meal	3.52	3.52	2.13	2.13
Corn gluten meal	2.80	2.80	1.68	1.68
Ground corn	3.19	3.17	5.59	5.57
Limestone	1.12	1.12	1.12	1.12
Urea	------	------	0.11	0.11
Trace mineralized salt[1]	0.50	0.50	0.50	0.50
Choice white grease	0.28	0.28	0.28	0.28
Vitamins A,D,E[2]	0.03	0.03	0.03	0.03
Aureomycin-90[3]	------	0.02	------	0.02

[1] 92.00% NaCl, 5,500 ppm Zn, 4,790 ppm Mn, 1,835 ppm Cu, 9,275 ppm Fe, 115 ppm I, 65 ppm Co, and 18 ppm Se. [2] 8,800 IU/g vitamin A, 1,760 IU g^{-1} vitamin D, and 1.1 IU g^{-1} vitamin E. [3] Added to supply 350 mg of CTC per day per stee

After the backgrounding period, steers were limit-fed two transition diets for an additional 30 d at 90% of the previous ad libitum intake. These transition diets consisted of 75:25 and 85:15 concentrate-forage, respectively, and were fed for adjustment to ad libitum intake of the experimental diet (Table 1). Ad libitum intake of the experimental diet was established incrementally over a 7-d period during the transition period, immediately prior to beginning the experiment. Steers were blocked by body weight (BW; 6 blocks), assigned randomly to pen within their respective block, and pens were assigned randomly to a 2 x 2 factorial arrangement of treatments within block. Treatments included feed containing either 0 or 39.6 ppm (DM basis) CTC (Aureomycin, Alpharma Animal Health, Fort Lee, NJ) and Revalor-S® or no Revalor-S® (120 mg trenbolone acetate + 24 mg 17-β estradiol benzoate, Intervet Inc., Millsboro, DE). The level of CTC used in this study provided approximately 350 mg CTC/steer/d and was the same as the level used in previous experiments by[4-6]. Steers assigned to receive Revalor-S were implanted on d 1 and re-implanted on d 63. The experimental diet was formulated using two protein supplements: Protein supplement 1 was formulated to provide 105% of the Metabolizable Protein (MP) requirement for large-frame steers (345 kg BW) gaining 1.60 kg d^{-1} and was fed until d 63 of the experiment; Protein supplement 2 was formulated to provide 105% of the MP requirement for large-frame steers (450 kg BW) gaining 1.20 kg d^{-1} and was fed from d 63-125 or 139 [13]. Steers were fed daily at 0900. Once weekly, orts were measured and the amount of feed offered was adjusted to maintain approximately 10% orts. Individual diet ingredients were sampled weekly and analyzed for DM content. Weekly determinations of DM content were used in the adjustment of the amount of feed offered the following week.

Body weights were measured every 28 d before feeding. Initial and final BW were determined by weighing steers on two consecutive days. Ultrasound was used on a subset of steers (approximately 8-10 steers) from the heaviest blocks (Blocks 5 and 6) to determine the amount of subcutaneous fat over the 12th rib on d 118. Because these steers met or exceeded 12 mm of backfat, it was determined that they had completed the finishing phase. On d 125, these steers were transported to a commercial slaughter facility and killed the following day. Subsequently, the remaining 4 blocks of steers completed the finishing phase on d 139 and were killed on d 140. A merit evaluation of each carcass was done according to USDA standards and performed by a qualified meat scientist the following day. Carcass quality indicators were longissimus muscle area, fat over longissimus muscle, kidney, pelvic, and heart fat (KPH), marbling, and bone maturity.

Statistical analyses: Growth performance and carcass data were statistically analyzed by analysis of variance for a randomized complete block (weight) design with a 2 x 2 factorial arrangement of treatments using PROC GLM procedures of SAS (SAS Inst., Inc., Cary, NC, 2003). Pen was the experimental unit and the model included block, CTC, implant, and the interaction of CTC and implant. All blocks of animals were used for growth performance calculations through d 125, while only blocks 1-4 were used for growth performance calculations from d 126-139 (blocks 5 and 6 were killed on d 126). When interactions were significant ($p \leq 0.10$), protected Fisher's LSD were used to separate effects of implant within each level of CTC.

RESULTS

Growth Performance: Average daily gain, Dry Matter Intake (DMI), and efficiency of gain (BW gain per unit of DMI) are summarized in Table 2. Over the course of the entire experiment (d 0-139), CTC reduced ($p = 0.02$) DMI by 0.4 kg d^{-1} compared to steers receiving no CTC, while implanted steers gained 0.4 kg d^{-1} more ($p = 0.0001$) BW than non-implanted steers. Overall, there was an interaction ($p = 0.03$) between CTC and implant for efficiency of gain. In the absence of CTC, implanted cattle gained 31% more efficiently than non-implanted cattle, whereas in the presence of CTC, implant only resulted in a 20% increase in feed efficiency ($p<0.0001$).

During the early part of the finishing phase (d 0-84), Revalor-S increased ADG and efficiency of gain 25% and 26%, respectively, above that of non-implanted steers ($p = 0.01$). During periods of this same phase, implant and CTC decreased DMI by an average of 0.5 kg d^{-1} (d 0-28 and d 29-56, respectively; $p = 0.05$). Although the decrease in DMI contributed to an increase in ADG for the implanted steers (d 0-28), it did not affect efficiency of gain for the steers fed CTC (d 29-56). There were no effects ($p = 0.13$) of CTC on ADG or efficiency of gain during the rest of this phase.

During the latter part of the finishing phase (d 85-139), interactions occurred between CTC and implant ($p \leq 0.07$) for ADG and efficiency of gain. In the absence of CTC, implanted steers gained an average of 0.74 kg d^{-1} more than non-implanted steers ($p \leq 0.007$), but in the presence of CTC, implant had no effect ($p = 0.13$). Additionally, there was a significant ($p \leq 0.07$) interaction between CTC and implant for efficiency of gain. In the

Table 2: Effects of oral chlortetracycline (CTC) and Revalor-S on dry matter intake (DMI), average daily gain (ADG), and efficiency of gain of finishing beef steers[a]

	-CTC		+CTC		P <			
Item	-Implant	+Implant	-Implant	+Implant	SEM[b]	CTC	Implant	X[c]
Period 1, 0-28 d								
Initial BW, kg	401	402	400	401	1.55	0.11	0.53	0.75
DMI, kg d^{-1}	8.95	8.15	8.41	8.24	0.23	0.35	0.05	0.19
ADG, kg d^{-1}	1.90	2.12	1.74	2.19	0.26	0.72	0.01	0.37
Gain:DMI, g/kg	211.40	261.93	208.62	265.55	11.88	0.97	0.0004	0.79
Period 2, 29-56 d								
DMI, kg d^{-1}	9.61	9.51	9.01	9.06	0.18	0.01	0.91	0.68
ADG, kg d^{-1}	1.42	1.83	1.36	1.67	0.22	0.28	0.003	0.64
Gain:DMI, g/kg	149.29	192.84	151.28	185.83	11.48	0.83	0.004	0.70
Period 3, 57-84 d								
DMI, kg d^{-1}	9.15	8.94	8.33	9.07	0.29	0.25	0.38	0.12
ADG, kg d^{-1}	1.37	1.61	1.05	1.58	0.25	0.14	0.004	0.21
Gain:DMI, g/kg	150.60	180.03	126.12	173.61	9.64	0.13	0.001	0.36
Period 4, 85-112 d								
DMI, kg d^{-1}	8.78	9.26	9.05	9.52	0.23	0.28	0.06	0.98
ADG, kg d^{-1}[de]	1.15	1.90	1.62	1.88	0.26	0.08	0.0006	0.06
Gain:DMI, g/kg[de]	130.69	214.78	179.39	195.92	11.15	0.20	0.0004	0.008
Period 5, 113-139 d								
DMI, kg d^{-1}	9.11	10.70	9.50	10.33	0.36	0.97	0.005	0.32
ADG, kg d^{-1}[d]	0.93	1.65	1.14	1.21	0.36	0.51	0.03	0.06
Gain:DMI, g/kg	103.33	160.34	123.27	120.17	15.36	0.52	0.10	0.07
0-139 d								
DMI, kg d^{-1}	9.28	9.34	8.82	9.02	0.15	0.02	0.390	0.65
ADG, kg d^{-1}[d]	1.39	1.84	1.40	1.74	0.08	0.25	0.0001	0.18
Gain:DMI, g/kg[dfg]	152.53	200.37	159.08	190.21	3.37	0.60	0.0001	0.03
Final BW, kg[h]	587	647	586	632	11.67	0.16	0.0001	0.19

[a]Chlortetracycline fed at 350 mg of CTC per day per steer. [b]Standard error of the mean calculated from analysis of variance using n=6
[c]Interaction of CTC x implant. [d]In the absence of CTC, implant means differ ($p = 0.02$). [e]In the absence of implant, CTC means differ ($p = 0.01$)
[f]In the presence of CTC, implant means differ ($p<0.0001$). [g]In the presence of implant, CTC means differ ($p = 0.05$). [h]Slaughtered at d 126 or 140

Table 3: Effects of oral chlortetracycline (CTC) and Revalor-S on carcass quality measures in finishing beef steers[a]

	-CTC		+CTC		P <			
Carcass quality measures	-Implant	+Implant	-Implant	+Implant	SEM[b]	CTC	Implant	X[c]
Longissimus area, cm^2	85.32	84.26	83.60	84.19	0.26	0.60	0.89	0.63
Longissimus fat cover, cm	1.21	1.12	1.14	1.07	0.03	0.81	0.60	0.64
KPH fat, %	2.06	2.04	2.10	2.04	0.03	0.53	0.22	0.53
Marbling[d]	4.41	4.07	4.33	4.25	0.20	0.80	0.30	0.53
Yield grade	2.99	3.08	3.06	3.03	0.12	0.90	0.80	0.64

[a]Chlortetracycline fed at 350 mg of CTC per day per steer. [b]Standard error of the mean calculated from analysis of variance using n=6. Interaction of CTC x implant. [d]Scores: 1.00 = trace[00], 2.00 = slight[00], 3.00 = small[00], 4.00 = modest[00]

absence of CTC, implanted steers gained 60% more efficiently than non-implanted steers ($p \leq 0.02$); however, implant had no effect ($p \geq 0.31$) in the presence of CTC. Additionally, DMI tended to increase ($p \leq 0.06$) by 0.84 kg d^{-1} for implanted compared to non-implanted steers. Chlortetracycline had no effect ($p \geq 0.28$) on DMI during this phase of finishing.

Carcass Quality. There were no interactions ($p \geq 0.53$) between CTC and implant for carcass quality measures (Table 3). There were no effects ($p \geq 0.22$) of treatment on longissimus dorsi area or fat cover, KPH fat, marbling, or yield grade.

DISCUSSION

The objective of the current experiment was to determine if CTC and an anabolic implant containing estradiol benzoate + trenbolone acetate interact to affect growth performance and carcass characteristics of finishing beef steers. Because it has been demonstrated that CTC has the ability to increase subcutaneous and intramuscular fat deposition[5,14,15] and anabolic implants containing trenbolone acetate + estradiol benzoate have been shown to reduce marbling score and the percentage of carcasses grading Choice[5,11], it is of interest to determine if CTC can transcend the antagonistic effects of an anabolic implant and increase the deposition of intramuscular fat. Over the course of the entire experiment, implanted steers had greater ADG; however, an interaction between CTC and implant for feed efficiency revealed that the presence of CTC slightly attenuated the response to implantation. Furthermore, this interaction was a result of treatment effects that occurred late in the finishing period, specifically in the last 27 d. There were no effects of CTC or Revalor-S on carcass characteristics, most notably those involving fat deposition. These results are inconsistent with our hypothesis, considering that previous research has shown CTC and Revalor-S to positively and negatively affect fat deposition, respectively.

Growth Performance: It is a common practice to implant cattle in the finishing phase of growth using different ratios of estradiol benzoate and trenbolone acetate, depending on stage of finishing (e.g., d 1-70 vs. d 71-140). These combinations of estrogens and androgens account for an additive growth response in cattle, commonly increasing ADG and improving feed efficiency above those of cattle receiving estrogenic implants alone[8] Although the mechanism for such increases in ADG and feed efficiency remains somewhat ambiguous, it is known that androgens possibly inhibit release of hormones that cause muscle degradation, thus increasing protein accretion above that of estrogenic implants alone[16]. In the current experiment, it was expected that implant would positively affect ADG, which increased approximately 28% compared to non-implanted steers. This finding agrees with previous research using trenbolone acetate + estradiol benzoate implants in which ADG increased 21% in implanted steers approximately 127 d on feed[7,9,10,17]. Additionally, this improvement in ADG was considerably greater than the 16% increase in ADG of steers implanted with progesterone + estradiol benzoate (Synovex-S) in previous studies averaging 108 d[10,17,18,19]. These data, in conjunction with previous research, indirectly support the idea that implants containing trenbolone acetate + estradiol benzoate improve ADG to a greater extent than those containing progesterone + estradiol benzoate.

In part, the overall increase in ADG for the current experiment was due to an improvement in ADG of 25% for cattle receiving Revalor-S during the initial 84 days. However, in the absence of CTC, there was a greater improvement in ADG (71%) for implanted compared to non-implanted steers during the final 55 days of the finishing phase. These results demonstrate that not only did Revalor-S increase ADG above that of non-implanted steers during the early phases of finishing, but the improvements were even more dramatic during the latter phase of finishing, considering that non-implanted cattle normally deposit adipose tissue as a greater proportion of empty body gain during this time [20,21]. Furthermore, other research has shown that steers receiving a synthetic androgen plus estradiol had increased protein and less fat in their final empty body gain[16], suggesting a greater priority for lean tissue growth with an anabolic implant. Although protein accretion was not measured directly in the current experiment, the improvement in ADG for implanted steers observed throughout this experiment suggest that the combination of androgen and estrogen may have increased protein accretion, possibly by repartitioning compositional gain away from fat and towards protein deposition in this group of animals[8-16]. Although the mechanism explaining lower ADG for steers receiving CTC in the presence of implant is unknown, an explanation may be related to thyroid hormone function. Rumsey *et al.*[4] demonstrated that subtherapeutic administration of CTC decreased GH and thyroid hormone responses to a TRH + GHRH challenge in growing steers over a 91-d period. More recently, Kitts et al. (2005, submitted) showed a greater triiodothyronine (T_3) response for steers implanted with Synovex-S (200 mg progesterone + 20 mg 17-β estradiol benzoate) than those receiving no implant in the absence of CTC. Triiodothyronine was not affected by implant in the presence of CTC. Although the implant used contained progesterone + estradiol benzoate, in the current experiment it is possible that, at least during the final period, the decrease in ADG for non-implanted and implanted steers in the presence of the CTC may have been associated with decreased thyroid function through an unknown mechanism which subdued the rate of BW gain.

Chlortetracycline and implant interacted to affect efficiency of gain for the entire experiment (d 0-139). Implanted steers gained more efficiently both in the absence and presence of CTC; however, the improvement in efficiency of gain for implanted steers in the presence of CTC was only 20%, compared to a 31% increase in the absence of CTC. This finding suggests that CTC may have attenuated an improvement in efficiency of gain for implanted steers. Furthermore, this decrease in efficiency of gain is a function of the numerically lower ADG for implanted steers in the presence of CTC. Although it is not altogether surprising that in the absence of implant, CTC had no positive effect on ADG and efficiency of gain as we have previously shown no effect of CTC these parameters[6], it is a unique observation that the improved efficiency of gain for implanted steers was slightly diminished in the presence of CTC. This interaction between CTC and implant regarding efficiency of gain results from similar interactions that occurred late in the finishing phase (d 85-139); there was an increase in efficiency of gain for steers implanted in the absence, but not presence, of CTC. It is possible that the lower efficiency of gain occurring in the presence of CTC and implant during the last 27 d was due to both an increase in DMI for implanted steers ($p = 0.005$) and no positive effect of implant on ADG in the presence of CTC ($p = 0.79$).

Although there was no effect of CTC on most parameters of growth during the finishing phase, DMI decreased an average of 0.4 kg d^{-1} for steers fed CTC compared to steers receiving no CTC. The reason for this decrease in intake is unclear; previous studies which included oral, subtherapeutic levels of CTC in the diets of finishing steers and lambs showed no effect of CTC on DMI[22,23]. Although the steers receiving CTC in the current experiment consumed less during Period 2, this decrease in intake did not translate to a significant reduction in ADG or efficiency of gain. The effects of subtherapeutic, oral administration of CTC on ADG and efficiency of gain have been shown to be variable. Earlier research has demonstrated increased BW gain and efficiency in growing but not finishing steers, whereas other data suggests improvements in weight gain for feedlot steers[7]. The lack of effect of CTC on ADG and efficiency of gain seen in the current experiment has also been observed in previous experiments by Rumsey *et al.*[5] and Kitts *et al.*[6]. Although the reason for these discrepancies is unclear, it has been suggested that the effects of CTC on growth performance are more apparent under stressful conditions that are immunologically challenging to the animal[1]. In both the current study and those of[5,6], steers were vaccinated and backgrounded for a minimum of 30 d, and adjusted to the experimental diet prior to initiation of the experiment.

Carcass Quality: In previous research involving anabolic implants containing trenbolone acetate + estradiol benzoate, the effects of this implant on carcass characteristics have been variable; however, most research has shown that an implant containing estrogen + a synthetic androgen such as trenbolone acetate negatively affects marbling score and often, decreases the percentage of carcasses grading Choice[1-24,25]. Although monetary benefit is realized through an increase in ADG and feed efficiency with these anabolic implants, a decrease in marbling and thus, lowering quality grade from Choice to Select reduces the value of a carcass. Therefore, it is of interest to develop strategies which allow producers to benefit from improved ADG and feed efficiencies associated with growth implants, while finding other compounds capable of improving marbling scores in concert with implants. The results of the current experiment showed a lack of change in longissimus area or fat cover and marbling and therefore reflects no effect of implant on compositional gain. However, these results do not preclude the possibility that compositional gain was altered during Period 4 (d 85-112), when an interaction between CTC and implant occurred for ADG. There was no effect of implant or CTC on the remaining carcass characteristics. These results disagree with most previous research showing lower marbling scores and percentage of carcasses grading Choice in steers implanted with Revalor-S[10-17-24,25]. Conversely, CTC fed to steers has increased longissimus fat cover and numerically increased marbling scores[5] and increased the number of carcasses grading Choice[7]. Furthermore, longissimus muscle area has been shown to be greater when Revalor-S was used in finishing cattle[5-9-24]. Interestingly, none of these effects were seen in the current experiment demonstrating that, at least in this group of animals, Revalor-S did not negatively, and CTC did not positively, affect carcass quality.

In summary, Revalor-S increased ADG over the course of the finishing period as expected; however, the positive effect of implant on feed efficiency was partially attenuated in the presence of CTC. This attenuation appears to be a function of both DMI and ADG. Although CTC reduced DMI, the putative mechanism responsible for this interaction is unclear; it appears to be manifested through changes in both DMI and ADG, neither of which are mutually exclusive variables. Additionally, inconsistent with previous observations, carcass quality traits in the current experiment were not affected by either Revalor-S or CTC. Because Revalor-S did not negatively affect carcass quality, this shows that growth implants containing estrogen + synthetic androgens positively affect growth performance, while not discounting carcass value. These data clearly illustrate the need for further research to identify potential interactions between anabolic implants and CTC regarding feedlot performance.

REFERENCES

1. Visek, W.J., 1978. The mode of growth promotion by antibiotics. J. Anim. Sci., 46:1447-1469.
2. Landagora, F.T., L.L. Rusoff and B. Harris, Jr. 1957. Effect of chlortetracycline on carcass yields including physical and chemical composition of dairy calves. J. Anim. Sci., 16: 654-661.
3. McLeod, K.R., R.L. Baldwin, VI, T.S. Rumsey, T.H. Elsasser, S. Kahl and M.N. Streeter, 2003. Influence of subtherapeutic chlortetracycline and dietary protein on circulating concentration of insulin-like growth factor-1 in growing beef steers. J. Anim. Vet. Adv. 2:531-535.
4. Rumsey, T.S., K. McLeod, T.H. Elsasser, S. Kahl and R.L. Baldwin, 1999c. Effects of oral chlortetracycline and dietary protein level on plasma concentrations of growth hormone and thyroid hormones in beef steers before and after challenge with a combination of thyrotropin-releasing hormone and growth hormone-releasing hormone. J. Anim. Sci., 77: 2079-2087.
5. Rumsey, T.S., K. McLeod, T.H. Elsasser, S. Kahl and R.L. Baldwin, 2000. Performance and carcass merit of growing beef steers with chlortetracycline-modified sensitivity to pituitary releasing hormones and fed two dietary protein levels. J. Anim. Sci. 78:2765-2770.
6. Kitts, S.E., J.C. Matthews, G.L. Sipe, K.K. Schillo, T.S. Rumsey, T.H. Elsasser, S. Kahl, R.L. Baldwin, VI and K.R. McLeod, 2005. Effects of chlortetracycline (CTC) and Synovex-S® on growth rate and on plasma Growth Hormone (GH) and thyroid hormone concentrations following administration of Thyrotropin-Releasing Hormone (TRH) and GH-releasing hormone (GHRH) in beef steers. J. Anim. Sci. Submitted.
7. Perry, T.C., D.G. Fox and D.H. Beerman, 1991. Effect of an implant of trenbolone acetate and estradiol on growth, feed efficiency, and carcass composition of Holstein and beef steers. J. Anim. Sci., 69: 4696-4702.
8. Herschler, R.C., A.W. Olmsted, A.J. Edwards, R.L. Hale, T. Montgomery, R.L. Preston, S.J. Bartle and J.J. Sheldon, 1995. Production responses to various doses and ratios of estradiol benzoate and trenbolone acetate implants in steers and heifers. J. Anim. Sci., 73: 2873-2881.
9. Johnson, B.J., P.T. Anderson, J.C. Meiske and W.R. Dayton, 1996. Effect of a combined trenbolone acetate and estradiol implant on feedlot performance. carcass characteristics, and carcass composition of feedlot steers. J. Anim. Sci., 74: 363-371.
10. Hermesmeyer, G.N., L.L. Berger, T.G. Nash and R.T. Brandt, Jr, 2000. Effects of energy intake. implantation, and subcutaneous fat end point on feedlot steer performance and carcass composition. J. Anim. Sci., 78: 825-831.
11. Platter, W.J., J.D. Tatum, K.E. Belk, J.A. Scanga and G.C. Smith, 2003. Effects of repetitive use of hormonal implants on beef carcass quality, tenderness, and consumer ratings of beef palatability. J. Anim. Sci., 81: 984-996.
12. McKenna, D.R., D.L. Roebert, P.K. Bates, T.B. Schmidt, D.S. Hale, D.B. Griffin, J.W. Savell, J.C. Brooks, J.B. Morgan, T.H. Montgomery, K.E. Belk and G.C. Smith, 2002. National Beef Quality Audit-2000: survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci., 80: 1212-1222.

13. NRC. 2000. Nutrient Requirements for Beef Cattle (7th Rev. Edn.). National Academy Press, Washington, D.C.
14. Bohman, V.R. and M.A. Wade, 1958. The effect of certain feed additives on the tissues of fattening beef cattle. J. Anim. Sci., 17: 124-132.
15. Harvey, R.W., M.B. Wise, T.N. Blumer and E.R. Barrick, 1968. Influence of added roughage and chlortetracycline to all-concentrate rations for fattening steers. J. Anim. Sci., 27: 1438-1444.
16. Solis, J.C., F.M. Byers, G.T. Schelling and L.W. Greene, 1989. Anabolic implant and frame size effects on growth regulation, nutrient repartitioning and energetic efficiency of feedlot steers. J. Anim. Sci. 67: 2792-2801.
17. Mader, T.L., J.M. Dahlquist, M.H. Sindt, R.A. Stock and T.J. Klopfenstein, 1994. Effect of sequential implanting with Synovex on steer and heifer performance. J. Anim. Sci., 72: 1095-1100.
18. Rumsey, T.S., T.H. Elsasser, S.A. Norton, A.S. Kozak and S. Kahl, 1992. Influence of thyroid status regulation and Synovex-S implants on growth performance and tissue gain in beef steers. Domest. Anim. Endocrinol., 9: 173-180.
19. Rumsey, T.S., T.H. Elsasser and S. Kahl, 1999a. Performance and digestibilities of beef cattle fed diets supplemented with either soybean meal or roasted soybeans and implanted with Synovex. J. Anim. Sci., 77: 1631-1637.
20. Byers, F.M., 1982. Nutritional factors affecting growth of muscle and adipose tissue in ruminants. Fed. Proc., 41: 2562-2566.
21. Owens, F.N., D.R. Gill, D.S. Secrist and S.W. Coleman, 1995. Review of some aspects of growth and development of feedlot cattle. J. Anim. Sci., 73: 3152-3172.
22. Erwin, E.S., I.A. Dyer and M.E. Ensminger, 1956. Effects of chlortetracycline, inedible animal fat, stilbestrol and high and low quality roughage on performance of yearling steers. J. Anim. Sci., 15: 710-716.
23. Bolsen, K.K., E.E. Hatfield, U.S. Garrigus, P.E. Lamb, and B.B. Doane, 1968. Effects of sources of supplemental nitrogen and minerals, level of chlortetracycline, and moisture content of corn on the performance of ruminants fed all-concentrate diets. J. Anim. Sci., 27: 1663-1668.
24. Roeber, D.L., R.C. Cannell, K.E. Belk, R.K. Miller, J.D. Tatum and G.C. Smith, 2000. Implant strategies during feeding: Impact on carcass grades and consumer acceptability. J. Anim. Sci. 78:1867-1874.
25. Reiling, B.A. and D.D. Johnson, 2003. Effects of implant regimens (trenbolone acetate-estradiol administered alone or in combination with zeranol) and vitamin D_3 on fresh beef color and quality. J. Anim. Sci., 81:135-142.