Performance and carcass merit of growing beef steers with chlortetracycline-modified sensitivity to pituitary releasing hormones and fed two dietary protein levels[1,2,3]

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ABSTRACT: This paper reports the effects of reduced sensitivity to growth hormone-releasing hormone and thyrotropin-releasing hormone through feeding a subtherapeutic level of chlortetracycline (CTC; 350 mg CTC/d) and two levels of dietary CP (10% and 13% of diet DM) on growth performance and carcass merit characteristics. Thirty-two steers (initial average BW, 286 kg) were adapted to a common 13% CP diet consisting primarily of grass hay, corn, and soybean meal fed to gain 1.25 kg/d. The steers were assigned to four treatments (with or without CTC and 10% or 13% dietary CP in a factorial arrangement) and fed ad libitum amounts of diet for 91 d. Feed intake was determined daily and steers were weighed weekly. Steers were killed at the end of the feeding period for carcass merit determinations. Efficiency of BW gain was greater ($P < .05$) for steers fed the 13% CP diet than for the 10% CP diet and tended to be less for CTC-steers when the 10% CP diet was fed and greater for the CTC-steers when the 13% CP diet was fed (CTC × dietary CP interaction, $P < .10$). Feeding CTC increased ($P < .01$) fat over the longissimus muscle and marbling. This study is interpreted to indicate that the sustained effect of subtherapeutic feeding of CTC to cattle appears to increase fat deposition consistent with a reduced growth hormone and thyroid status reported earlier for these same steers. This would tend to increase energy utilization but may not necessarily produce a measurable increase in BW gain.

Key Words: Beef Cattle, Carcass Quality, Chlortetracycline, Performance, Protein Intake

 J. Anim. Sci. 2000. 78:2765–2770

Introduction

A growth-promoting effect of feeding subtherapeutic levels of chlortetracycline (**CTC**) has been reported for ruminants, swine, and poultry, but the mechanism for this effect is not known. Most hypotheses for growth promotion by antibiotics in ruminants relate to effects on digestive tract microorganisms or gut wall thinning (Visek, 1978). Based on carcass composition of calves, Landagora et al. (1957) suggested that CTC may influence growth via an endocrine axis. However, there is a void of information on effects of antibiotics on endocrine regulation of growth in ruminants.

Rumsey et al. (1999) demonstrated a reduced somatotropin (GH), thyroid-stimulating hormone (**TSH**), and thyroxine response to a challenge injection of thyrotropin-releasing hormone (**TRH**) plus growth hormone-releasing hormone (GHRH) in the steers in this report. These findings are consistent with the antithyroid effect of CTC shown by Calesnick et al. (1954) in rats and by Hsu et al. (1970) and Yok (1975) in chicks. Additionally, Holtzman and Visek (1965) reported reduced maintenance requirements in rats fed CTC. Chlortetracycline binds Ca^{+2} (Gershengorn and Thaw, 1982), which is involved in cytoplasmic release of hormones by TRH. Chlortetracycline also reduces hypothalamic deiodinase activity (Rumsey et al., 1999). These effects may be factors that attenuate pituitary response to releasing hormones and in turn influence growth and tissue deposition.

The purpose of the present study was to determine whether the practical measures of performance and car-

[1]The authors gratefully acknowledge D. Carbaugh and A. Kozak for technical assistance, R. Zephir and J. Piatt for abattoir assistance, P. Graninger for animal management assistance, and M. Solomon for carcass merit evaluation.

[2]The chlortetracycline and partial funding for this study were provided by Roche Vitamin, Inc., Animal Nutrition and Health, Parsippany, New Jersey.

[3]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by USDA and does not imply its approval to the exclusion of other products that may be suitable.

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Received October 7, 1999.
Accepted May 8, 2000.

Table 1. Adaptation and experimental diets[a]

Ingredient, % DM	Adaptation diet[b]	Experimental diet[c] 10% Protein	13% Protein
Cracked corn	41.0	43.5	36.5
Wheat straw	—	20.0	20.0
Cottonseed hulls	—	20.0	20.0
Orchard grass hay	40.0	—	—
Black-strap cane molasses	9.0	—	—
Dehydrated cane molasses	—	9.0	9.0
Soybean meal, 48%	8.0	5.5	12.5
Trace-mineralized salt[d]	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0
Vitamins A, D, and E[e]	(+)	(+)	(+)

[a]For all diets, hay and straw were ground through a 10-mm screen and pelleted through a 9.5-mm dye.
[b]Diet was formulated to contain 13% CP (NRC, 1984).
[c]Composition of the 10 and 13% CP diets were 10.3 and 13.4%, respectively, for CP (analytical) and 2.41 Mcal ME/kg DM (calculated; NRC, 1984) for both diets.
[d]Trace mineral concentration (g/kg): Mn, 2.00; Fe, 1.60; Cu, .33; S, .11; Co, .10; Zn, .10; I, .07.
[e]Provided 2,497,000 IU vitamin A, 550,000 IU vitamin D_3, and 275 IU vitamin E per 1,000 kg of diet (as fed).

cass merit characteristics are detectably different between control steers and steers with reduced sensitivity to pituitary-releasing hormones (TRH and GHRH) in response to a subtherapeutic feeding of CTC (350 mg CTC/d top-dressed on morning feed; Rumsey et al., 1999). In addition, a protein-sparing effect was tested by feeding two levels of dietary CP (10% and 13% of diet DM).

Materials and Methods

Animal Care. The animal protocol for the research in this report was approved by the Beltsville Agricultural Research Center Institutional Animal Care and Use Committee.

Experimental Protocol. Forty-four young crossbred beef steers of predominantly Angus breeding were purchased at an annual fall feeder calf sale in central Virginia. Selection of lots of steers for purchase was based on visual appraisal of uniformity of BW and body condition. Calves were initially housed on pasture for 30 d upon arrival at the Beltsville Agricultural Research Center, during which time they were dewormed and treated orally with griseofulvin (Fulvicin U/F, Schering-Plough Animal Health Corp., Kenilworth, NJ) for dermatomycoses or ringworm, a problem that was particularly bad in the Eastern United States during the fall, winter, and spring of 1996–97 seasons. After 30 d, 32 selected steers were placed in individual pens and adapted over a 6-wk period to the adaptation diet (Table 1). The steers continued to be housed in these pens for the duration of the subsequent experimental period. Each pen was 1.6 × 9.1 m located on a concrete pad fully covered with a roof. The steers had continuous access to an automatic watering bowl.

During adaptation, steers were fed an intake level based on metabolizable energy to gain 1.25 kg/d (NRC, 1984). Standard protocol during this adaptation period was that steers were turned out of their pens into a common exercise lot daily at 0600 for approximately 2 h. During this time their pens were cleaned and the daily allotment of fresh feed was added to their feeders. There were no orts at this limited intake level. Adaptation to handling and a halter was accomplished by returning steers from exercise to their pens via the animal working chute system and by haltering in pens for approximately 1 h daily. During the last week of the 6-wk adaptation period, for all steers, a step-up to an ad libitum level of intake was started.

At the end of the 6-wk adaptation period, steers were assigned to four groups to equalize average BW across groups in a 2 × 2 factorial arrangement of treatments (with or without CTC and 10% or 13% dietary CP, Table 1). The diets were formulated on the basis of ME and CP using NRC (1984) so that ME was equalized across CP level. The basic diet formulation has been used in several previous feedlot studies at the Beltsville Agricultural Research Center. The treatments containing CTC and not were accomplished with a daily top-dress of either 500 g of corn meal carrier or 500 g of carrier plus CTC (Aureomycin, Hoffmann-La Roche Inc., Paramus, NJ) to provide 350 mg CTC/d. The level of CTC was that recommended by the manufacturer for cattle of the BW range in this study. The CTC treatments were accomplished by placing 1 kg of experimental diet in each feeder at 0800, top-dressing with carrier or carrier plus CTC, and briefly paddle-mixing. After this initial portion of the diet was consumed, the remainder of the daily allotment of feed was placed in the feeders, typically by 1000. The animal-handling protocol during the experiment was the same as during the adaptation period, except that daily haltering was not continued. Orts were measured daily immediately after the steers were turned out for exercise and throughout the study feed offered was adjusted to maintain approximately 10% orts.

After 56 d on the experimental treatments, all steers were challenged with a combination of TRH and GHRH to test responsiveness of the pituitary. Details of this protocol and results of this challenge study have been reported previously (Rumsey et al., 1999). After 91 d on the experimental diets, steers were slaughtered in groups of four steers per day over a period of 2 wk for determining carcass merit indicators. Each group contained one steer from each treatment, and selection for Groups 1 through 8 was from heaviest to lightest within each treatment. Steers were slaughtered in the USDA abattoir at the Beltsville Agricultural Research Center following a 24-h feed withdrawal. Carcass merit evaluation was done according to USDA standards and performed by a qualified meat scientist. The carcass merit indicators were slaughter weight; dressing percentage; longissimus muscle area; fat over longissimus muscle; kidney, pelvic, and heart fat; marbling; and bone maturity.

All steers were weighed on two consecutive days at the beginning and end of the experiment and once weekly during the adaptation period and the experiment. A BW measurement was also obtained just before moving the steers to the abattoir for slaughter.

Statistical Analysis. Based on feed intakes and BW, the first 28 d of the trial were considered an adaptation to ad libitum feeding and diet treatment, which started on d 0, and d 29 to 91 were considered the growth trial period. For gain, DMI, and efficiency of gain, an analysis was conducted using the GLM procedure of SAS (1989) within the d-0 to d-28 period (Period 1) and within d-29 to d-91 (Period 2). The model used was for a 2 × 2 factorial with CTC and CP level as main effects. Body weight gain was determined by regressing BW over days for Period 1 and for Period 2. Carcass merit data were analyzed by GLM as a 2 × 2 factorial with CTC, CP level, and slaughter group as main effects. Slaughter group was removed from the model when not significant ($P > .10$).

Results and Discussion

Performance. Body weight gain (calculated as the slopes of the weekly BW data over time), DMI, and efficiency of gain (BW gain per unit of DM intake) by treatment are summarized in Table 2. There were no treatment effects ($P > .10$) on performance during Period 1, although gain efficiency was numerically 11% greater for steers fed the adequate (13%) CP diet than for steers fed the marginal (10%) CP diet. Body weight gain was greater during Period 1 than expected. However, BW curves and changes in plasma IGF-I concentrations (Baldwin et al., 1998) over time (data not shown) suggested that steers were adapting to the experimental diets and to the ad libitum level of intake during Period 1. The higher than expected gains for Period 1 probably included a large component of fill gain as a confounding factor influencing performance.

For Period 2, average BW gain across treatments averaged 1.5 kg/d. This is consistent with expected BW gains based on average nutrient intakes in this trial. Actual daily intake for Period 2 averaged 10.4 kg of DM, and DM intakes were similar across treatments ($P > .10$). This DM intake represented approximately 25.1 Mcal ME, and 1.1 and 1.4 kg of protein for the 10% and 13% CP experimental diets, respectively, in support of the average BW gain of 1.5 kg/d. Using values from Table 10 of NRC (1984) for 409-kg medium-frame steers, daily intake values to support a BW gain of 1.4 kg/d are 9.0 kg DM, .9 kg protein, and 27.5 Mcal ME. For 409-kg large-frame steers, daily intake values to support a BW gain of 1.6 kg/d are 9.6 kg DM, 1.0 kg protein, and 27.2 Mcal ME. The steers in this study (average BW 393 kg) were crossbred and judged to score between medium- and large-frame steers.

One objective of the current study was to test a protein-sparing effect of CTC, as has been suggested by Meade (1956) for swine. Calculated dietary CP concentrations of 10% and 13% were used; 10% considered marginal and 13% considered adequate for steers at 350 kg BW. The 10% CP level was considered marginal for the steers in this study, particularly during the earlier weeks of Period 2, but not inadequate to the degree that ruminal fermentation would be compromised, which in turn could reduce ad libitum intake. Intake was not influenced by CP level ($P > .10$), averaging 10.6 and 10.2 kg DM/d for the 10% and 13% CP diets, respectively. Although this study was designed using the CP system from NRC (1984), values for TDN and DIP calculated from NRC (1996) indicated that DIP was sufficient to support theoretical BCP efficiencies within the range of literature values (NRC, 1996).

For Period 2, gain efficiency was greater ($P < .05$) for steers fed the 13% CP diet than for steers fed the 10% CP diet. There was only a trend ($P < .10$) for a CTC ×

Table 2. Effect of oral chlortetracycline[a] (CTC) and dietary CP level on body weight gain, feed intake, and efficiency of gain

	CP, 10%		CP, 13%			P <		
Item	−CTC	+CTC	−CTC	+CTC	SEM[b]	CTC	CP	×[c]
Period 1, 0 to 28 d								
Initial BW, kg	285	283	287	288	5.9	ns[d]	ns	ns
Dry matter intake, kg/d	8.8	9.0	8.7	8.3	.32	ns	ns	ns
Body weight gain, kg/d	2.26	2.29	2.38	2.33	.12	ns	ns	ns
Gain:DMI, g/kg	256.5	254.4	272.6	294.2	18.5	ns	ns	ns
Period 2, 28 to 91 d								
Initial BW, kg	346	346	351	351	7.3	ns	ns	ns
Dry matter intake, kg/d	10.7	10.5	10.5	9.9	.61	ns	ns	ns
Body weight gain, kg/d	1.58	1.33	1.63	1.64	.11	ns	ns	ns
Gain:DMI, g/kg	149.1	126.0	155.2	179.4	13.6	ns	.05	.10

[a]Chlortetracycline (Aureomycin, Hoffmann-La Roche, Inc.) was fed at 350 mg of CTC per day per steer.
[b]Standard error of the mean calculated from analysis of variance using n = 8.
[c]Interaction of CTC × CP level.
[d]Not significant ($P > .10$).

CP level interaction. When steers were fed the 10% CP diet, efficiency was lower for the steers fed CTC than for the steers not fed CTC, and when fed the 13% CP diet, efficiency was greater for the steers fed CTC than for the steers not fed CTC. This does not support a protein-sparing effect of CTC, as has been suggested. The possibility of a protein-sparing effect of CTC in swine has been summarized by Meade (1956), although Meade (1956) was not successful in demonstrating this effect.

The trend for CTC to improve efficiency of BW gain under conditions of adequate nutrition is consistent with previous reports in the literature, when a response was observed. However, responses to CTC in growing and finishing cattle have been variable, with some studies revealing only slight numerical differences. Bohman et al. (1957) reported an improvement in BW gain in steers in only the second of three feeding periods. Bolsen et al. (1968) reported an improvement in BW gain in one of three trials, and Harvey et al. (1968) reported nonsignificant but slight numerical increases in BW gain. Erwin et al. (1956), Perry et al. (1958), and Heinemann and Fanelli (1963) found CTC to improve BW gain. Perry et al. (1954) reported improved BW gains and efficiency in both suckling and yearling steers but not in finishing steers when CTC was fed, and Brown et al. (1975) reported that CTC improved BW gain and slightly improved efficiency in feedlot steers.

As in cattle, an early conclusion by Jordan et al. (1956) was that lamb BW gain response to antibiotics was inconsistent. In suckling lambs, CTC increased BW gain in three trials but not in a fourth (Jordan and Bell, 1954). For finishing lambs, Jordan (1952) reported both a slight improvement in BW gain (one trial) and slower gain (three trials) when CTC was fed, whereas Bridges et al. (1953) reported a slight improvement in BW gain and an improvement in feed efficiency. Subsequently, Kunkel et al. (1956), Jordan (1958), and Ternus et al. (1971) reported no improvement in performance when CTC was fed, whereas Calhoun and Shelton (1973) reported improved BW gain or feed efficiency with CTC. If CTC affects the partitioning of nutrients via a hypothalamic-pituitary mechanism, then a growth response may be variable depending on nutritional status, type of diet (i.e., energy level), and physiological age, all of which are confounding factors when comparing the outcomes of the above-cited lamb trials.

Carcass Merit. Carcass merit data are summarized in Table 3. Slaughter weight was greater ($P < .04$) for steers fed the 13% CP diet than for steers fed the 10% CP diet, and slaughter weight tended to be less ($P < .06$) for steers fed CTC than for steers not fed CTC. However, carcass weight, dressing percentage, and longissimus muscle area were not affected by treatment ($P > .10$). Longissimus fat cover was greater ($P < .01$) for steers fed CTC than for steers not fed CTC for both the 10 and 13% CP diets. Additionally, marbling tended to be greater ($P < .10$) in steers fed CTC than in steers not fed CTC for both the 10 and 13% CP diets. These results suggest greater fat deposition in the carcasses of steers fed CTC, consistent with those reports in the literature that have shown an effect on the carcasses of cattle and sheep when CTC is fed.

As reported for BW gain and efficiency, the effect on carcass merit has been variable. Harvey et al. (1968) reported nonsignificant but slight numerical increases in marbling and dressing percentage for CTC-fed steers. Although Bohman et al. (1957) found no effect of CTC on carcass quality, Heinemann and Fanelli (1963) reported a consistent numerical trend for improved carcass grade in CTC-fed steers, and Perry et al. (1958) reported a significant improvement in carcass grade when CTC was fed to steers. Bohman and Wade (1958) reported a slightly greater amount of separable rib fat for steers fed CTC. In general, although small, the studies with cattle suggest a trend toward increased fat deposition in CTC-fed steers.

For growing and finishing lambs, Bohman et al. (1955) and Kunkel et al. (1956) reported no effect of CTC on carcass grade. Johnson et al. (1956) reported increased BW gain and efficiency, but carcass data were compromised because of their need for early slaughter of the finishing lambs. However, Hatfield et al. (1954) obtained an improvement in both BW gain and carcass grade for CTC-fed lambs. In subsequent studies in which BW gain of finishing lambs was not improved, Jordan et al. (1956) reported carcass grade was slightly improved by CTC and Raun et al. (1962) reported higher carcass grade, separable fat, and dressing percentage for CTC-fed lambs. In two of three lamb trials, Rumsey et al. (1982) reported that CTC improved BW gain and dressing percentage. In those trials in which carcass evaluation was included, there tended to be a consistent indication that greater fat deposition resulted from CTC feeding in finishing lambs.

With dairy calves given CTC either orally or intramuscularly (Rusoff et al., 1954), BW gains, separable meat, and percentage of fat in meat were greater than for controls, particularly for calves treated intramuscularly. Others have also reported increased BW gains for CTC-treated calves (Lassiter et al., 1955; Landagora et al., 1957; Wing, 1957).

For swine, results of the effect of CTC have been variable, as with cattle and sheep. As an example, Clawson et al. (1955) and Wallace et al. (1955) found that BW gains tended to be greater under certain conditions with no effect on carcass composition or carcass merit. Subsequently, Kelly et al. (1957) reported that, for barrows, CTC improved BW gain as well as absorptive blood fat levels and backfat thickness. This was pointed out to be in agreement with a trend toward greater carcass fatness as suggested by other physical and chemical measures. Greater fat deposition as opposed to muscle deposition does not agree with a report by Hathaway et al. (1996), indicating that plasma IGF-I was increased in pigs treated with ASP-250. However, in the current study, we did not find an increase in IGF-I associated with CTC feeding except during the

Table 3. The effect of oral chlortetracycline (CTC)[a] and dietary CP level on carcass evaluation measures of growing beef steers

	CP, 10%		CP, 13%			P <		
Item	–CTC	+CTC	–CTC	+CTC	SEM[b]	CTC	PRO	×[c]
Slaughter weight, kg	450	433	457	452	5.5	.06	.04	ns[f]
Carcass weight, kg	258	251	261	260	3.6	ns	ns	ns
Dressing percentage	57.3	58.0	57.1	57.5	.5	ns	ns	ns
Longissimus area, cm^2	65.6	63.7	65.0	66.1	1.9	ns	ns	ns
Longissimus fat cover, cm	.30	.36	.29	.42	.03	.01	ns	ns
KPH fat, %	1.44	1.44	1.19	1.52	.13	ns	ns	ns
Marbling[d]	2.3	2.6	2.2	2.8	.2	.08	ns	ns
Bone maturity[e]	1.4	1.4	1.4	1.5	.1	ns	ns	ns

[a]Chlortetracycline (Aureomycin, Hoffmann-La Roche, Inc.) was fed at 350 mg CTC per day per steer.
[b]Standard error of the mean calculated from analysis of variance using n = 8.
[c]Interaction of CTC × CP level.
[d]Scores: 2.00 = slight^{00} to 3.00 = small^{00}.
[e]Scores: 1.00 = A^{00}.
[f]Not significant ($P > .10$).

initial 2 wk of the trial (Baldwin et al., 1998). There may be a transient time effect of CTC, or IGF-I may be influenced by the other antibiotic components of the ASP-250 formulation.

The reported results for steers, lambs, calves, and swine in which CTC has affected carcass measurements are generally consistent with the endocrine effects of CTC observed for steers in the current study, in which reduced GH and TSH response occurred in these steers following a challenge injection of TRH plus GHRH (Rumsey et al., 1999). Also, the results are consistent with reports that show CTC to have an antithyroid effect in rats (Calesnick et al., 1954) and chicks (Hsu et al., 1970; Yok, 1975) and to reduce maintenance requirements in rats (Holtzman and Visek, 1965).

In summary, growing beef steers, in which the pituitary sensitivity to TRH and GHRH was reduced by oral CTC, displayed increased fat deposition consistent with a reduced GH and thyroid status. This would tend to increase energy utilization but may not necessarily produce a measurable increase in BW gain if, under certain conditions, nutrients are being preferentially used for fat deposition instead of protein deposition. Additional work is needed to determine how the specific effects of feeding CTC to cattle as suggested by this study interact with other proposed mechanisms of CTC action and what effects nutritional status, type of diet, and physiological age have on the response to CTC.

Implications

A feeding study was conducted to determine the differences in performance and carcass merit of growing beef steers with chlortetracycline-reduced sensitivity to pituitary releasing hormones and fed under conditions of marginal (10%) and adequate (13%) dietary protein. A sustained effect of subtherapeutic feeding of chlortetracycline to cattle appears to be increased fat deposition, consistent with a reduced growth hormone and thyroid status under both marginal or adequate protein conditions. This would tend to increase energy utilization but may not necessarily produce a measurable increase in body weight gain if relative muscle and(or) fat deposition rates are changing in opposing directions.

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